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WHY I PAY MY DUES

G. W. MUNRO,
Chairman, Membership Committee

Like most teachers I am a member of a number of technical, scientific and professional societies. Of these I find the S. P. E. E. one of the most satisfactory.

I have attended the four annual meetings, Urbana, Ithaca, Schenectady and Chapel Hill. At each I have met people facing the same problems I face daily—a classroom full of would-be, will-be and will-never-be engineers. At these meetings, the sessions of the teachers of English have broadened my vision and sympathies; from the meetings of the Deans and Administrators I have acquired a new insight into the efforts made to adjust curricula to unprepared students at one end and to unprepared industry at the other. The general sessions have been of help by presenting a wealth of helpful ideas and devices by master craftsmen in the art of teaching. The meetings have been very satisfying.

The JOURNAL too has been a source of enjoyment. It deals with problems which are mine, and every issue has contained items of interest and help to me. Moreover, on those rare occasions when I could no longer repress myself the JOURNAL was the medium through which I reached my desired audience —my fellow teachers of engineering students. The JOURNAL has been a real factor in my teaching life.

The investigations undertaken by the S. P. E. E. have proved to be both interesting and illuminating. As an example take the problems of the unfit student, the inadequate plant and the underpaid instructor, which once seemed to be local. It appears now that these problems are nationwide and the solutions, if any, lie in national rather than in local movements.

The meetings of our Local Section have also been valuable.

Here at Purdue we meet two or three times a year as the guests of some one department which analyzes its own problems showing their relation to those of the university as a whole. From these meetings I have been enabled to obtain a clearer conception of the problems and tasks which face our departments of English, Modern Language, Chemistry, Physics and Mathematics than would have been possible through any other contact.

The Summer Schools for teachers of engineering students is one of the newer and most valuable activities of the society. Although, special short courses in athletic coaching, the technique of teaching physical education, have been given in Summer Schools for many years, instruction in the technique of technical instruction was not offered until two years ago when the society initiated this movement. It is my sincere hope that these summer sessions of engineering teachers will be extended until every young engineering teacher can secure expert coaching in the art of teaching, at very moderate cost.

Perhaps, the foregoing may help to explain why I have paid my dues for thirteen years with the growing consciousness that the money has been well spent. My only regret is, that I failed to join the S. P. E. E. until I had taught for nine years, and presumably the fault is not mine as no one asked me to join, nor was the value of membership known to me.

Now, as one of the membership committee, I desire that each teacher of engineering students should know the advantages of membership as I know them. To this end, I have endeavored to describe briefly those benefits which have appealed to me most strongly. Also, I ask that the members make note of other satisfactions which have resulted through contacts with the Society, so they may be embodied into a single comprehensive leaflet for the information of teachers who are not members.

Kindly send statements to me at West Lafayette, Indiana.

THE 1929 SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS.

The generous cooperation and financial support of the American Society of Mechanical Engineers, Purdue University, and the Western Electric Company have definitely assured the holding of the 1929 session of the Society's Summer School. As previously announced in the *Journal*, the session will be devoted to mechanical engineering and will be held at Purdue University from June 27 to July 18, inclusive.

Plans for the program of the session have been completed along the general lines previously described. The first three days are devoted to general meetings attended by all members, with lectures and discussions dealing with the following topics:

Aims and Purposes of Mechanical Engineering Education,
Present Trends in Higher Education,
Purposes and Scope of Courses in Heat Power Engineering,
Purposes and Scope of Courses in Mechanism and Machine Design,
Purposes and Scope of Courses in Production Engineering,
The History of Mechanical Engineering,
General Principles of Teaching,
"How to Conduct Lectures and Recitations,"
College Personnel Methods,
"Specificity vs. Generalization in Learning,"
"Teaching the Student How to Study."

A good deal of the balance of the program is divided into three major divisions with meetings held simultaneously for the groups of teachers interested primarily in Heat Power Engineering, in Mechanism and Machine Design, and in Production Engineering.

The program of the Heat Power Division begins with discussion of the teaching of general concepts, principles and

definitions, and proceeds through properties of gases and vapors, gas and vapor cycles, flow of fluids, fuels and combustion, combustion equipment, heat transfer, steam generating equipment, steam power auxiliaries, metering, and other related topics. A definite sequence similar to that of the major course in Heat Power Engineering is followed. Emphasis is to be placed constantly upon methods of teaching the various topics.

The Machine Design Division of the program similarly follows a sequence of topics relating to that division of mechanical engineering, including among others: analysis of motion, transmission of motion, kinematic principles, machine parts, application of principles of mechanics in machine design, design of machine tools, materials of construction, and the planning of class work in machine design theory and practice.

The Production Division of the program includes discussion of the teaching of the principles and methods of management, production control and personnel administration, and the administration, aims, purposes, and methods of engineering shop laboratories. The Production Division also includes work at the Hawthorne Plant of the Western Electric Company, to be described later.

At intervals during the part of the program devoted to divisional meetings, sessions of the entire group are held on topics of interest and importance to all teachers of mechanical engineering. The general method is followed of having the introductory and general lectures relating to major subjects of instruction or important topics given first before the entire group and of following these with more detailed consideration and more informal discussion in the group meetings. One entire day is to be devoted to the teaching of values and costs and to the economic practices and the finance of industrial enterprises. Both teachers and practitioners will take part in this session.

On July 10, 11, and 12 the entire summer school group will move to Chicago for an intensive study of administration, production and personnel methods at the Hawthorne Works of the Western Electric Company, the largest manufacturing unit

of the Bell Telephone System. The program to be followed at Hawthorne is especially interesting and promises to be of great value to the members. It includes lectures on the organization plan of the Works, description of the physical plant and product, principles of production control, description of production control methods, purchasing policies, materials handling, inspection and testing, cost control methods, manufacturing development, and personnel policies and methods, including the recruitment and development of engineering college graduates. The lectures are to be supplemented by inspection of the production methods employed in the Works and the witnessing of the several steps in the manufacturing processes employed in connection with selected items of telephone equipment. The party will also witness the manufacture of wire and cable, one of the most interesting processes at the Works.

Upon return to Purdue on July 12, the general and divisional meetings meetings are resumed. Toward the end of the session provision is made for the submission and discussion of reports prepared by committees of the members relating to various problems connected with the teaching of mechanical engineering. These include such topics as "Heat Power Courses for Non-Mechanical Engineering Students," "Purposes and Methods of Design Courses," "Purposes and Methods of Courses in Administration and Management," "Inspection Trips," and others. Several periods are devoted to engineering laboratory work, including inspection of the Purdue laboratories and to the study and discussion of methods pursued in conducting laboratory exercises.

Certain of the evenings during the session are set aside for general lectures and for round table discussions. Provision is also made for recreation, including an overnight trip to Turkey Run Park, a picnic on July Fourth, and for golf and other sports. The members will be extended guest privileges at two country clubs.

Practically all of the members of the staff to whom invitations to serve have been extended have accepted and are now announced:

LOCAL DIRECTOR OF THE SESSION

A. A. Potter, Dean of the Schools of Engineering, Purdue University.

SECRETARY

H. L. Solberg, Assistant Professor of Mechanical Engineering, Purdue University.

LECTURERS ON EDUCATIONAL PRINCIPLES AND METHODS

C. H. Judd, Director, School of Education, University of Chicago.

Edward C. Elliott, President, Purdue University.

HEAT POWER DIVISION

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G. W. Munro, Professor of Thermodynamics, Purdue University.

C. F. Hirshfeld, Chief Research Department, Detroit Edison Company.

W. J. Wohlenberg, Professor of Mechanical Engineering, Yale University.

C. H. Berry, Professor of Mechanical Engineering, Harvard University.

E. G. Bailey, President, Fuller-Lehigh Company; President, Bailey Meter Company.

E. F. Miller, Professor of Steam Engineering, in charge of the Department of Mechanical Engineering, Massachusetts Institute of Technology.

MACHINE DESIGN DIVISION

O. A. Leutwiler, Professor of Mechanical Engineering Design, University of Illinois.

R. C. H. Heck, Professor of Mechanical Engineering, Rutgers University.

H. F. Moore, Research Professor of Engineering Materials, University of Illinois.

E. A. Muller, President, King Machine Tool Company.
S. Timoshenko, Professor of Engineering Mechanics, University of Michigan.
F. Hodgkinson, Consulting Mechanical Engineer, Westinghouse Electric and Manufacturing Company.
S. W. Dudley, Professor of Mechanical Engineering, Yale University.
C. B. Veal, Research Manager, Society of Automotive Engineers.
(Lecturer on Materials Handling Equipment, to be announced later.)

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G. M. Williams, President, Marmon Motor Car Company.
S. A. Lewisohn, Vice President and Treasurer, Miami, Copper Company.
Richard Lieber, Director, Department of Conservation, State of Indiana.
G. A. Young, Professor of Mechanical Engineering, Purdue University.
Ira N. Hollis, Former President, Worcester Polytechnic Institute.
John Johnston, Director of Research, United States Steel Corporation.
E. P. Warner, Assistant Secretary of the Navy for Aeronautics.

As in past years all members of the summer school group will live together for the period of the session. Purdue has set aside Franklin Cary Hall, one of the university dormitor-

ies, for the use of the party. The building provides smoking rooms, an assembly room, and a dining hall, as well as bed rooms.

Expenses of attendance, aside from traveling, include a registration fee and the cost of room and meals. These will not exceed a total of sixty dollars for the duration of the session.

Over forty applications to attend the School have already been received. This article is intended to call the attention of others who may wish to attend to the fact that it is advisable to file applications at an early date. The limit of attendance has been set at seventy-five.

As an evidence of the cordial support the Society's Summer School receives, permission has been secured to quote the following communication from President Edward C. Elliott of Purdue University:

> "Purdue University has gladly accepted its full share of responsibility for the 1929 Summer School for Engineering Teachers. The University not only appreciates but anticipates the opportunities presented. We regard this Summer School as a national cooperative enterprise for the betterment of engineering teaching throughout the country. Along with the other agencies concerned, we want it to be a professional success. Purdue craves even more than this. We would that those who come will not only find themselves working enthusiastically but also gaining, for the years to come, pleasing memories of living on the Banks of the Wabash."

MEMBERS.

Last year Professor J. H. Cissel of Michigan wrote Professor A. P. Poorman of Purdue on behalf of the membership committee, requesting a personal canvass to secure new members for the S. P. E. E.

This work has been going on as time and circumstance afforded opportunity. Seventeen new members have been added to the sixty-two Purdue Staff members already enrolled, a gain of more than twenty-five per cent.

This illustrates how ready the teachers of engineering students are to join our Society once the value of S. P. E. E. membership is called to their attention.

The present membership committee has a local representative in each engineering college and asks for him the active cooperation of all members. This can be given in many ways, particularly in calling attention of colleagues not members, to the benefits and pleasures derived from S. P. E. E. contacts.

COLLECTED PAPERS OF THE PHYSICS SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS, JULY, 1928

The following pages give condensed versions of a number of the lectures and discussions of the Physics Session of the Summer School for Engineering Teachers, held at the Massachusetts Institute of Technology during July, 1928. Limitations of space make condensation of the lectures necessary. Others are omitted for the same reason. In almost all instances the lectures were followed by general discussion by the entire group, but these discussions must also be omitted. The papers selected for publication are those relating most directly to the teaching of physics and to the principles of teaching in general. Others dealing less directly with the problems of teaching could not be included. They are available, however, in manuscript form at the office of the Director of Investigation, Society for the Promotion of Engineering Education, 33 West 39th Street, New York City, and may be consulted there.

OBJECTIVES OF UNDERGRADUATE COURSES IN PHYSICS FOR ENGINEERING STUDENTS*

By W. S. Franklin, *Professor of Physics*, Massachusetts Institute of Technology,

July 9, 1928.

Professor Franklin began by saying that he would first make some general observations concerning what seemed to him to be the two most important aspects of present-day physical science.

The first relates to the ability of the trained physicist to hold things in mind. Such concepts as the kinetic theory of gases constitute an actual working model of the gas as it exists in one's mind. Every physicist knows how this helps to keep

* A somewhat more extended account of Professor Franklin's lecture will be found in *Science* early in 1929.

facts concerning gases in mind and how it helps one to think about them. Helmholtz referred to this when he said, "It is nevertheless a great help if we form in every case the most concrete physical picture, even when the picture contains many an assumption that is not in all strictness necessary."

The second aspect relates to the extent to which quantitative mathematics can be tied to physical conditions and things. Every quantitative notion in physics is or grows out of a precise idea. Thus acceleration is a precise idea. In tying quantitative mathematics to physics nothing is so essential as precise ideas and it is remarkable that such bare things as precise ideas should open the mind to an almost endless array of simple perceptions previously non-existent. The teaching of precise ideas, Professor Franklin said, seems certainly now to be the main objective of the teaching of physics in college and in the engineering school, and, although some teachers of physics can perhaps neglect this objective to some extent, the teacher of physics to engineering students cannot neglect it at all, and it holds in the preparation of young men for research even more rigorously than in preparation for practical work.

Training in analytical thinking seems so all-important that nothing else need be mentioned in the consideration of the objective of the teaching of physics. It must be analytical thinking which relates to actual physical conditions and things. As Bacon has said, "Our method is to dwell among things soberly without abstracting or setting the mind farther from them than makes their images meet; and the capital precept for the whole undertaking is that the eye of the mind be never taken off from things themselves, but receive their image as they truly are; and God forbid that we should ever offer the dreams of fancy as a model of the world."

"One hundred and fifty years ago," Professor Franklin said, "Pascal made the statement that the only faculty needed in the student, if one is to be able to implant precise ideas in his mind, is eyesight; but, as Pascal says, 'it must be good eyesight because precise ideas and principles are so minute.'

This means that precise ideas and fundamental principles as they are held in the mind are framed out of sense material."

To illustrate Pascal's meaning, Professor Franklin considered the principle of work and gave as a definition of work the following:

"(*a*) When a body on which a force acts moves in the direction of the force, the force does work, and

"(*b*) The amount of work done in any given time is equal to the product of the force and the distance the body has moved in the direction of the force." He then gave the following statements of this definition, which are commonly used:

"(*a'*) A force does work when it overcomes resistance.

"(*a''*) A force does work when it moves a body.

"(*b'*) The work done by a force is found by multiplying the force by the distance through which it acts."

Professor Franklin criticized these definitions as lacking in precision. Concerning (*a'*) he asked "What is meant by resistance? Did anyone ever see resistance? Did anyone ever feel resistance? For of course when Pascal asks us to see a thing he means that we are to apprehend it by the senses. When one pulls on a body he feels the backward pull of the body on the hand. This reaction may be due to a variety of causes, however. It may be due to the fact that the body is being accelerated or to the fact that it is subject to friction, or to the fact that it is pulled by another force, etc. It is the reaction, and not the resistance, that is felt."

Concerning statement (*a''*), Professor Franklin asked, "What is meant when one says that a force moves a body?" He pointed out that one of the most troublesome misconceptions in beginning the study of dynamics is the mistaken idea that the effect of unbalanced force is to "move" a body. The effect of such a force is to *accelerate* the body.

Concerning statement (*b'*), Professor Franklin said that the essential absence of meaning is illustrated by the answers given to the following problem by about 35 per cent of a group of engineering students: "A 10 foot rope is tied to a post and the post is pulled by a 50 lb. force applied to the end

of the rope. How much work is done?'' The 35 per cent mentioned calculated the work as 500 foot-pounds, because, as they sensed the problem, the 50 lb. force acts *through a distance* of 10 feet.

As another example of Pascal's meaning, it is to be remembered that in every case in simple mathematics a force is exerted on a body by something which is in contact with it, excepting only the pull of gravity or of magnetic or electrical forces which are like gravity in that the ''ropes'' which tie them to bodies are invisible. A ball is tied to a string and twirled in a circle. What forces act on the ball? Gravity, of course, acts on the ball, the string pulls on the ball, and the air exerts a force on the ball, but no other forces whatever act upon it.

Good examples of Pascal's meaning are to be found in every phase of every branch of physics and what he says is almost universally applicable in implanting precise ideas in the minds of students.

Professor Franklin then dealt with the building up of precise ideas by definition. ''Every statement of principles and every definition in physics,'' he said, ''are actual operations; things done by the hand, when you come to fathom their meaning; and in very many cases they are such complicated operations that they must be highly idealized to avoid endless and confusing circumlocutions in specifying them.'' As an illustration, he mentioned the first law of thermodynamics which defines heat as a form of energy. ''It is not very difficult,'' he said, ''to phrase a definition of this law so that it is in terms of things to be done. Take a body *a* and produce in it a change of thermal condition by doing a certain amount of work on it, then bring *a* back to its initial state by bringing it in contact with another cooler body *b*. Then it will be found that the thermal change produced in *b* is exactly that which would have been produced if the original work had been expended on *b* directly. That is to say, the body *a*, by virtue of the change produced in it by the original work, contains something which is exactly equivalent to the work in the re-

stricted sense that *a* in being brought back to its initial state, can produce exactly the same thermal change in body *b* as could be produced by the original work, and this something we call heat. The definition of heat as a form of energy is completely fixed by the specified result of the specified operation."

The statement of the principle of the conservation of energy that "energy can be neither created nor destroyed" is one that no one can possibly understand, although it is easy to make use of it in many physical problems without understanding it. If one wishes to know precisely what it means one must specify the underlying operations.

In speaking of the real versus the adventitious difficulties encountered by the student of physics, Professor Franklin said that he often has students come to him a year or so after completing the first course in physics with the question "why is such and such a text so difficult?"—and he has always answered, "because the author did not and does not know how to make his treatment intelligible." Nothing is difficult after it has been done or found out, but the commonest fault with worth-while texts is their unnecessary difficulty to the student.

Professor Franklin said that from experience he knows that most students like physics when the teaching is directed insistently toward the development and use of precise ideas or toward what may be called training in analytical thinking, and he knows further that students can be carried far in this highly profitable business. In his experience interest in the study of physics is *not* dependent upon the introduction of descriptive physics, nor upon the application of its principles to practical engineering problems, except of the simplest kind; an almost purely analytical course in elementary physics arouses intense interest if one heeds Bacon's admonition and connects every detail of analytical method with actual conditions and things.

In conclusion Professor Franklin emphasized again his conviction that the only objective worth talking about in physics

is training in analytical thinking. "Increase of our powers of thought is the greatest gift of science to mankind."

PHYSICS IN ENGINEERING CURRICULA; A REVIEW OF PRESENT CONDITIONS

By A. W. Duff, *Professor of Physics,* Worcester Polytechnic Institute,

July 10, 1928.

Professor Duff stated that his remarks were based upon a report prepared by the Educational Committee of the American Physical Society as the result of a rather extended survey of about one hundred engineering schools made about six years ago.

From this report it was deduced that the subject of general physics occupies an average of about eight and one-half per cent of the time in the four-year engineering course. The average in the better schools is somewhat higher, twelve of the strongest showing about ten per cent of the time devoted to physics. The time varied widely from one school to another. "What is the amount of time that the Physics Department of an engineering school needs?" was a question which Professor Duff stated for the consideration of the meeting.

Professor Duff questioned the soundness of the wide variation among engineering schools as to the position of physics in the curriculum. The survey indicated that

38 per cent of the schools confine physics to the sophomore year,

22 per cent give physics in the freshman and sophomore years,

24 per cent give physics in the sophomore and junior years,

5 schools give physics in the freshman, sophomore and junior years,

4 schools give physics in the sophomore, junior and senior years.

"Where does physics belong in the four-year engineering course?" asked Professor Duff. He thought considerable var-

iations might reasonably exist, but believed that the question called for more careful consideration in each institution.

Professor Duff stated that practically no account is taken of the work in physics done in the high school, though most engineering students have had physics before entering college. This condition is unsatisfactory, but seems to be one that cannot be remedied, because in most cases the high school course is not given as a preparation for college work. Professor Duff does not claim that it should be, since only a minority of high school students go to college and a still smaller proportion go to an engineering school.

"What are we aiming at in physics courses?" was the next question. "Apparently we are not agreed," he said. In the survey above referred to, the heads of physics departments were asked to arrange the following aims in the order of their importance:

A—Scientific habits of thought,
B—Teaching the laws of physics,
C—Facts and methods of physics,
D—Accuracy of observation.

Of 89 schools replying, 39 place *C* last, 12 place *C* first or second, 17 place *B* first, 15 place *B* last. "Should there be such a diversity of opinion?" he asked.

"Are we to teach physics simply as an engineering tool to be used in the solution of engineering problems? Or should we bear in mind also the general education of our students? Should our students know the cause of the rainbow and what makes the sky blue or the setting sun red, and should they know the law of gravitation?" These were other questions which he thought teachers of physics should consider.

In connection with the general objects of physics teaching, Professor Duff quoted the following words written by Director Wickenden in the report of the Board of Investigation and Coordination, which he considered an excellent statement of general purposes:

"The basic process of an engineering education should be an undergraduate curriculum of coherent and integral structure directed to grounding the student in the principles and methods of engineering and in those elements of liberal culture which serve to fit the engineer for a worthy place in human society and to enrich his personal life."

As to forms of instruction, most schools agree that a combination of lectures, laboratory periods and recitations is the most effective; that sections for recitations should not exceed twenty-five in number and that problem work should occupy about one-fourth of the recitation time.

"Inquiry," said Professor Duff, "from teachers of engineering subjects as to what they think of the work done in physics reveals many favorable comments and some criticisms, such as: 'Material taught not retained by students; instruction not practical; important principles not stressed; students not taught to think; knowledge not available; students have not the engineering point of view;' are common."

"These criticisms should be met fairly and it is our purpose here to seek the remedies for our faults, if faults they be. In defense of the physics teacher, however, it may be said that physics is essentially a hard subject on account of the multiplicity of new concepts, new principles and new methods of thought. Compare, for example, the number of new concepts encountered in physics with the number met in applied mechanics, to which about an equal amount of time is given."

LAWS OF LEARNING

By Walter F. Dearborn, *Professor of Education*, Harvard University,

July 10 and 12, 1928.

In introducing his remarks, Professor Dearborn said, "The other day I asked a university professor of physics what a group of physicists such as this would most likely want in a discussion of the general laws of learning. He replied

promptly: 'They will want, in the first place, to be assured that there are some laws of learning, and, in the second place, they will want something practical.' In other words, as I interpreted the second remark, they will want to know how to make use of the laws of learning in the practice of teaching. And I said to myself if I can succeed in helping them to do this, and incidentally helping myself to do this, I shall have brought them and myself into the vanguard of teachers and in line with the best of present day notions in regard to the practice of teaching."

"For," he said, "the teaching process must take its cue from the learning process." Taking this as the first major point of his lecture, he discussed the sequence of events and the trends that have been developing in educational thought in the past few years. The first efforts to improve education were directed chiefly to the study of *what to teach*, with the teacher functioning principally as the dispenser of information. Next came a shift of emphasis to *methods of teaching*, with (quoting Glenn Frank) the "'methodizers playing gadfly to the old timers who were content to be merely retail merchants of canned information.'" Lately, however, "a second generation of gadflies to the methodizers has appeared.

"This new education makes the teaching process take its cue from the learning process—'Until day before yesterday, historically speaking, we made the learning process take its cue from the teaching process. Our schools have been organized for the benefit of the teachers instead of the students—our whole teaching technique has followed the logical lines of the teacher's organization of the subject matter in his field. The present approach to the educational process promises to give us schools in which there will be more learning and less teaching.'"*

From this it appears that a discussion of the laws of learning will necessarily imply the principles of teaching, and Professor Dearborn therefore proposed to deal with the two sub-

* From President Glenn Frank's Introduction to Harry Miller's *Creative Learning and Teaching*.

jects at the same time, instead of treating them separately in his two discourses.

Learning is now usually described in terms of "stimulus and response." There is no learning without reacting, and, contrawise, there is no learning without stimulation. Certain stimuli produce characteristic response, but other stimuli which would not in themselves seem sufficient, may come to produce these same responses. The study of the way in which this result comes about has lead to the formulation of the most fundamental law of learning which may be stated as follows:

"The stimulation of any receptor (or sense) organ occurring simultaneously with a reaction of an effector organ (as of muscle or gland) may lead to the formation of a new stimulus response bond."

Professor Dearborn illustrated the meaning of this law by citing the experiments of the Russian physiologist, Pavlov, which, while conducted with animals, indicate the fundamental law of learning. If, when Pavlov fed his dogs, he rang a bell or flashed a red light, after a few repetitions the bell or the light would produce the same response as the sight of the food itself. The food constituted an *unconditioned stimulus;* the bell or the light constituted the *conditioned stimulus* in the reaction. "This principle, now amply demonstrated in many fields, is that when an individual is responding to any stimulus or situation, any other stimulus occurring along with this first stimulus or as a part of the first situation may become in and of itself capable of producing a response for which it was originally totally inadequate.—'So far as we know (in the words of Watson), we can take any stimulus calling out a standard reaction and substitute another stimulus for it. And so far as we know we can take any response and substitute new stimuli for it.' It would thus appear that learning consists solely in the substitution of a new stimulus for an old stimulus to a given response, or the substitution of a new response instead of the old one which up to this moment a given stimulus has elicited. And—the teacher may appear either

as a new stimulus in the pupil's environment to produce some old but worthy responses, or as an old stimulus to produce some new responses."

Continuing this discussion of the psychology of learning, Professor Dearborn referred to the statements of James in regard to interest, in which he made use of the principle of the so-called conditioned response to the extension of which into all walks of life, of the learner as well as the teacher, he was directing attention. " 'An object not interesting in itself may become interesting through becoming associated with an object in which an interest already exists. The two associated objects grow, as it were, together: the interesting portion sheds its quality over the whole; and thus things not interesting in their own right borrow an interest which becomes as real and as strong as that of a natively interesting thing. The odd thing is that the borrowing does not impoverish the source, the objects together being more interesting, perhaps, than the originally interesting portion by itself.' "

This statement of James was formulated in terms of the older psychology—the law of association. The restatement of this law in the more objective terms of stimulus and response is the result of experiments in many lands which have also greatly extended its significance and multiplied as well as simplified its applications.

Passing from this statement of the basic law of learning, Professor Dearborn turned to some of its general applications to teaching, touching upon the following important points:

(1) If the unconditioned stimulus precedes the conditioned stimulus, there is no new reflex formed; whereas, if the conditioned stimulus precedes the unconditioned stimulus a new reflex is formed.

This principle has an important bearing in educational procedure which may be summarized as follows: *In learning an association, present the unfamiliar element first.*

Illustrating this point, Professor Dearborn continued (quoting Symonds), " 'The skillful teacher of history will present first the historical incident before presenting the more famil-

iar present related condition. Similarly in language, present the unfamiliar word or idiom before giving its English equivalent.' '' Applications of this principle in the teaching of physics will occur to everyone.

(2) Simultaneous conditioned reflexes are formed quickly. '' 'The new and the old should be presented as closely together in space and time as possible. If a new word is being learned, it should be presented adjacent to its synonym, the foreign word being presented first, if anything. If the association is between two visual stimuli, they should be placed as close together as possible so that the time interval between them is merely that represented by the time of the eye movement from one to another. This is probably an explanation of the value of a graphic representation for facilitating the portrayal of facts. It would seem as though the essential feature of effective presentation is the time necessary to make the comparison, and spacial contiguity is a most important factor. This would suggest that visual presentation should in general be more effective than auditory presentation. The time interval in visual presentation is limited only by the speed of eye movement. The time interval in auditory presentation is of necessity longer because one word cannot be spoken until another is finished. Probably the most effective form of presentation is a combination of visual and auditory, for then simultaneity can be approximated.' ''

(3) ''The rate at which the conditioned reflex becomes established is correlated with the strength of the conditioned stimulus. In general in school, learning depends more than is usually realized upon clearness and vividness of stimuli. Much of the effectiveness in learning depends on good light, clear print, good blackboard illustrations. The teacher's voice and enunciation are also important factors. The army has learned the value of sharp, clear, emphatic commands as a factor in the speedy learning of the manual of arms.''

(4) '' 'The vigor or strength of the conditioned response is proportional to the strength of the unconditioned stimulus. This law should be compared with the preceding law. The

speed of learning is proportional to the strength of the conditioned stimulus; the *strength* of the learning is proportional to the strength of the unconditioned stimulus. As an illustration, new words in a foreign language are more surely learned if they are associated with the best known synonym in English. Events or personages in history or places and processes in geography are the better remembered if they are associated with the most commonplace or familiar or contemporary events, personages, or processes.' " Similarly in physics, new laws are best learned when they are taught in such a way as to bring them into the realm of things with which the student is already thoroughly familiar *from his own experience.* This is the basis also for the use of illustrations, models, diagrams, demonstrations, etc., in teaching.

(5) " 'A conditioned reflex established to any given stimulus does not lead to the formation of other conditioned reflexes. This is the *law of specificity.* It is of great importance throughout all education. It denies categorically the possibility of transfer. Transfer only takes place when a new conditioned reflex is formed, in the regular way. Apparent cases of transfer take place only because some tenuous, highly aerated aspect or feature of the situation is the conditioned stimulus.' "*

This law of the specificity of learning indicates that a very common educational maxim has very wide application; it is that *one should learn things in the way in which they are to be used.* There is a problem here of wide significance which may be illustrated by a citation from the "Report on the Teaching of Physics" by the Educational Committee of the American Physical Society. Among the principles laid down is that the student's knowledge should be in an immediately available form.

Quoting from the remarks of an engineering teacher in that report: " 'It happens frequently in our first course in currents and dynamo machinery in this Electrical Engineering

* From Symonds, *Laws of Learning,* Journal of Educational Psychology, 1928.

Department that we ask questions the answers to which depend merely upon a working knowledge of the first course in physics, and the student's mind *appears* to be a blank; but usually well directed questions will discover that the student really knows all he needs to know to answer the question, but has no idea of the availability of his knowledge.' The teacher of engineering expects that the student should be able to use his physics as a tool, that he should know what tools he has and where to lay his hand on each in an emergency. Now the contents of the mind cannot be ticketed or card-catalogued. The only way to make general principles immediately available in a variety of emergencies, is first to see that the student starts with a sound, logically arranged body of simply connected principles, and then that he has such an extended practice in the use of these tools that the proper one comes to mind instinctively when its use is demanded. This again calls for extensive practice in physics classes on the application of general laws to concrete circumstances. It also calls for careful cooperation between teachers of physics and teachers of engineering in the choice and formulation of a body of fundamental principles."

Professor Dearborn followed this quotation by expressing the view that it is perhaps not so much the "choice and formulation of a body of fundamental principles" in which cooperation is needed as it is in the teaching and learning of the principles *in the ways in which they are to be used.* He said further that while he had a good deal of sympathy with the physicist who wishes to teach physics for physics' sake, he also believed that the point of view of the teacher of engineering when he has to pause to review a law of physics, must be considered. "Passing the buck" in education is due not so much to poor teaching as it is to the failure of teachers to reckon with the law of the specificity of learning. In view of the limitations of the learner, we should inquire how far he can escape the apparent limitations of the law of specificity and become able himself to "carry over" from one sort of learning to another. Each department should share in this

responsibility and not expect it to shift either one way or the other.

Quoting from Gates,* . . . "In learning of the factual type, part of the trouble is due to the notion, often accepted in practice if not in thought, that a fact is a fact and that it will function without regard to the way in which it was acquired. . . . This is completely to disregard the fact that what we learn . . . is not subject matter but, as elsewhere, particular reactions. . . . What we learn is the reactions that we make."

Students in learning an assignment on which they will subsequently expect to recite will learn best if, instead of simply spending their time in reading and rereading, they will spend just as much time as possible *in recall*—that is, in recalling to mind the specific things that have been read, because they are thus learning in the form in which they will use the information. Similarly students will best prepare if they actually practice the setting down of ideas in writing or propose for themselves lists of questions or possibly points on which they will be examined.

As a comment on this procedure, Professor Dearborn propounded the questions—"Is this worth while? Will it not simply make the student an automaton? It depends" he said, "partly on whether the student regards the making of good marks as an incidental or as a final goal. It also depends upon whether the examiner or teacher sets examinations or propounds questions that are worth while—fair approximations of what the student's final goal should be. So the engineering school which studies only the things which can be immediately applied is in danger of turning out merely the practical engineer who can do the tricks in which he has been trained, but lacks the breadth of vision and the insight to attempt new problems or to raise problems where there were supposed to be no problems. Now the man who can use his materials in the ways to be expected of him is not to be despised, but can this training also make for the more creative types of mind that are everywhere recognized to be the most

* Gates: *Psychology of Students of Education*, p. 266–7.

desired?" This, Professor Dearborn said, is the problem recognized in the report on The Teaching of Physics in stating that good learning and teaching should be such "that the student should be able to think for himself." Continuing his quotation from this report, Professor Dearborn said:

"It is not sufficient that he should be able to follow and assent to a line of reasoning presented by a teacher. He will have to do more than that in applying physics to industry. This, it must be admitted, is a very difficult, while also a very important requisite. It is, of course, an essential in all true education of any kind, but it is only by way of exception that it is attained in instruction in any subject. Teachers of engineering who complain that students cannot bring any initiative to bear in their thinking about physical principles often frankly admit that the same is true of the results in the subjects which they themselves teach. This, of course, does not excuse either the teacher of physics or the teacher of engineering, except so far as it shows that both are dealing with the disinclination of the average man to trust to his own resources in the matter of thinking. It is probable that the increase in recent times in the number of subjects studied in high schools has led to a less intensive form of instruction—more cramming and less thinking—with a consequent lowering of the capacity for deliberate thought.

"Probably the only two possible ways of teaching the student to think for himself are to *stimulate his interest* in the subject, and *give him practice* in thinking on original problems. How this can be accomplished in the very limited time allowed for the teaching of physics becomes a serious question. The view has sometimes been expressed by writers on education that the most effective form of teaching, especially for able students, would be to concentrate the instruction on suggestive laboratory work with extensive reading, the rate of progress being largely left to the student's own ingenuity and initiative. Such a course, while it might be highly desirable, would require much more time than is allowed in any college of engineering. Since the time necessary for such

a course cannot be allowed, it is difficult to see what can be substituted for the usual means of lectures, recitations, problem working, together with a limited amount of laboratory work. In the hands of competent, enthusiastic teachers these can be made effective, and we shall consider them in detail later."

Professor Dearborn stated that he would leave the main question of what is involved in creative learning and teaching till later and turn to one particular phase of the matter—how much "carry over" or "transfer" may be expected from specific learning.

This is one of the most debated problems, and one in which more experimental approaches have been attempted than, save for one or two exceptions, in any other phase of professional study of education. The results of these investigations seem to agree with the law of specificity deduced from physiological experiments. In this connection he quoted one very simple example from Buckingham *—"Winch found that drilling school children in computing, though it greatly increased their ability in that respect, had no clearly observable effect on reasoning in problem work. There are said to be forty-five basic combinations in addition. Teachers often act as if they supposed that the learning of these combinations would spread to all the necessary combinations in addition. This is not the case.

"In the first place, research has shown that not forty-five but one hundred combinations must be regarded as basic; for example, 2 plus 6 and 6 plus 2 are not the same. Clapp † has shown that among 1,154 third-grade pupils, 220 get 2 plus 6 wrong, whereas only 139 of the same children got 6 plus 2 wrong. . . . I do not mean that there is not a pronounced transfer from 2 plus 6 to 6 plus 2, but I do mean that after one has been learned the other will have to be separately learned, although very likely with less effort, especially if the two facts are associated in the teaching and learning.

* *Research for Teachers*, p. 42–45 inclusive.

† Clapp, Frank L., *The Number Combinations.*

"In the second place, . . . a pupil may know 2 plus 6 to the point of an invariably correct response, without knowing the derived facts 12 plus 6; 22 plus 6; etc. Osburn * points out unmistakably that each of these derived combinations is a new fact to be learned. No doubt a knowledge of 2 plus 6 will facilitate—that is, will transfer, to the learning of the corresponding derived facts, but it is doubtful if any but the most unusual child who knew any more than the basic combinations, would, without additional learning, be able to infer the derived facts.

"Accordingly, it is clear that you as teachers must in all your teaching steer between the assumption of total transfer and the assumption of no transfer. You must—and I think the evidence bears me out in this—recognize that in teaching there are two factors to be considerd, namely, a general factor and a specific factor. In the illustration from arithmetic, the general factor will tell us that in respect to the derived addition combinations the learning has been partly achieved through the previous learning of the basic combinations. At the same time the specific factor will tell us that this is not sufficient, that there must be a separate learning process with reference to the derived combinations themselves. The general factor corresponds to the transfer of training; the specific factor to the necessary direct frontal attack on each particular item to be learned."

Professor Dearborn pointed out that this example related to the learning of children and that the question naturally arose as to whether in the case of adults, and in particular in adults of superior intelligence, more transfer might be expected. "Age and intelligence do make for differences," he said, "but at least, as far as the experimental investigations go, the picture qualitatively is much the same, only spread on a larger canvass."

"Where there is partial identity,—that is, something in common between the old and the new training, this *may* facilitate the new learning. In this way, a knowledge of mathe-

* Osburn, W. J., *Corrective Arithmetic.*

matics helps the learning of physics, and physics helps the learning of engineering, but will the student who has learned the application of a law in one field be able to recognize the same process of application in another field? Evidently he may or may not. The engineer (as in the above quotation from the report on the Teaching of Physics) thinks in general that he should and is puzzled or believes him poorly taught if he doesn't."

"What is it," Professor Dearbon asked, "that makes for this difference between the 'carry over' of learning into one situation and the failure to 'carry over' into another? Why do students of apparently equal ability differ in respect to the generalizing of their training? The answer from experimental work is fairly precise." In support of this he quoted from a recent summary by Whipple.*

" 'The experimental work has made it evident that efficiency acquired in training may spread to related activities without any deliberate intent on the part of the person trained and in fact without his knowing what increased his efficiency or that any such factor was operating in the related activities. Perhaps it would be better to term this 'unintentional' or 'passive' or 'automatic' rather than 'unconscious' transfer. If it were not for this sort of transfer, the limitations of training would be far more serious than they are.' "

"But the experimental work has also made it evident that in many situations (and I think especially *in transfer through community of method*) transfer is either non-existent or decidedly limited unless the factors that are producing improvement in the training operations are consciously recognized and also consciously applied to bring about efficiency in the related operations. This is what Sleight refers to, for instance, when he says that *mere presence of an identical element is not enough; it must also be usable by its possessor.* The pedagogical moral is obvious: *Teachers should arrange the work of pupils and their own instructional efforts in such a way as*

* Whipple, G. N., *The Transfer of Training*, in the 1928 Year Book of the National Society for the Study of Education.

to facilitate the conscious recognition by the pupils of the methods by which efficient mental work is done."

Quoting an example cited by Whipple, Professor Dearborn said that if a student who is trying to commit to memory the outline of a map, discovers that he has to close his eyes and to attempt to see the map in his mind's eye, and subsequently, when being tested in committing to memory a list of words that he employs to advantage the same method, he has hit upon a knack (an incidental procedure which he finds useful in many kinds of learning). So the student who learns that he can best meet the tests of an examination by learning in the way in which his information and skill is required of him, may hit upon a procedure that will get him far in the practical world.

This leads to the important question concerning the student of physics who has learned to apply its laws in the course in physics, but fails to see the same process in the first course in currents and dynamo machinery or some other subject closely related to physics. Can the teacher of physics cultivate the attribute of mind, the way of looking at things so that a more or less generalized insight is possible? Professor Dearborn called the attention of his audience to some first aids to the problems suggested in Section 2 of the report on the Teaching of Physics by Educational Committee of the American Physical Society. These were given by teachers of physics in response to inquiries by the Committee. Such additional answers, Professor Dearborn said, as we can find, will be presented in a later discussion.

* * *

In beginning his second lecture on learning and teaching, Professor Dearborn again referred to the present trend of opinion concerning it. "All would agree," he said, "that teaching is something of a science and very much of an art. President Lowell, of Harvard, said in a recent address, that there were two schools of teaching; the one believed that if the teacher knew his subject, he did not have to know anything about the methods of teaching, and the other believed

that if the teacher knew the methods of teaching he did not have to know anything about the subject. A third school is now getting under way, however, whose thinking about teaching is becoming disconcerting to both of these more traditional schools. 'The teacher's first duty,' to recall a remark of President Glenn Frank, 'is to keep out of the student's way,' although we must note the more constructive statement is added that 'the teacher's highest function is to serve as stimulator and guide in the learning process.' "

" 'The educator's part in the enterprise of education,' " says John Dewey, " ' is to furnish the environment which stimulates response and directs the learner's course.' "*

Professor Dearborn quoted a number of other utterances to this same general effect and then continued by saying that since at any rate the point of departure is the pupil and his learning, we may well consider a little further what is going on at the center of the stage—that is, continue the discussion of the learning process. "Then we shall attempt to gauge the situation from the standpoint of the teacher and shall hope to show from further consideration of the learning process of the student that the teacher cannot be swept from the stage." There may be no learning without reacting, but there is also no learning without stimulation. If we are in the future to be more concerned than we have been in the past with the reactions of the student, we may find that we shall learn to be more concerned than in the past with the functions of the teacher as a stimulator.

"There are several corollaries to the general laws of learning," Professor Dearborn said, "that are of sufficient importance to be formulated as supplementary laws. They are:

1. The law of readiness.
2. The law of exercise, which may be subdivided into the law of use and disuse and the correlative law of recency.
3. The law of effect."

(1) The individual must be ready to respond. Students are sometimes "fed up" on a subject and are not ready for

* John Dewey, *Democracy and Education* (1916), p. 212.

any more learning of that sort. There are many conditions which affect the attitude of the learner and then the efficiency of his learning. The problem of interest is evidently involved here. Interest is not, as some one has remarked, "an entity for whose appearance we need passively wait;" it is, however, an indication that the student is ready to respond. If the resulting response is successful, the individual is on the next occasion all the more ready for further response. Interest becomes then a symptom of successful achievement. The prime conditioners of readiness to learn are the individual's maturity, intelligence and the previous learning. Standard tests of intelligence and of achievement may be an aid to the teacher in this connection. The best of them are simply tasks or miniature jobs to determine whether the student is ready to respond and if so, how well he is responding.

(2*a*) Buckingham says, "We learn by doing and we unlearn by not doing." There are occasions in which a single response may establish learning that a lifetime of disuse will not undo; but use or repetition is essential for most learning, and, other things being equal, the more recent the exercise of the function, the stronger are the connections. Deterioration of learning through disuse is a gradual process, but loss in the strength and of some sorts of learning may be observed even after the lapse of a few hours or days.

All of these statements are matters of common observation. There are some features which have only been disclosed by the most careful experimentation. Much of the analysis of the law of exercise as seen in such practical questions as to how long practice or drill should continue or what is the best distribution of the periods or work and the interval of time between work is only suggestive. Experimentation has rarely been on an extensive enough scale and with such materials that it can be directly applied in the fields in which we are interested in this discussion.

"It may be said that if one is to devote a given amount of time to study, short periods of work with rather long intervals between them are better than long periods with short intervals

of time. For example, Starch compared four different methods of using one hundred and twenty minutes in learning to associate numbers and letters as in learning a code. One group of subjects practiced ten minutes twice a day for six days, the second group, twenty minutes once a day, the third group, 40 minutes on three alternate days and the fourth group 120 minutes at one sitting. The efficiency of work was in the order named. There was little difference between the 10 and 20 minute groups; the 40 minute was much inferior and the 120 still more so."

The period of work can be too short. It varies with the individual and with the task. Professor Dearborn cited another experimental result antedating that above quoted, in which he found that 10 minutes a day of practice was superior to 5. He said, however, that there are various complications, depending upon what one wants to get out of the practice. This he illustrated by citing an experiment by Pyle * in typewriting, which covered a period of 90 half-hours of practice. "In such work as typewriting, distributed practice is best, but concentrated practice brings in good returns and if one is in a hurry to acquire skill the diminished returns from concentrated practice need not be considered prohibitive. In the above comparison, we have had in mind the same number of hours of practice. . . . If we consider merely the number of days spent in practice and disregard the total number of hours actually spent, we can say that 10 half-hours a day is better than 2 half-hours a day, . . . but if we consider the amount of time actually spent in practice we get more return for each hour of practice if the practices are spread out."

The length of the period of efficient work varies with the type of work as verbal, manual, logical, etc. Also longer periods are possible with advance in age, with superior intelligence and with previous practice in general and specific familiarity with a given type of work.

Some of the reasons offered as to why short period of work with generous intervals of time between them are better, are as follows:

* Pyle, *The Psychology of Learning*, p. 44.

An important part of the learning goes on during the periods of rest; the associations become settled and perfected. "This is the basis of James' comment that we learn to skate in summer and swim in winter." Professor Dearborn said that he did not believe the matter is quite as simple as this, but that time was not available to discuss it any more fully.

(2*b*) Jost's law of the age of associations is also called into play in connection with the law of exercise. This law is: "Of two associations which are of equal strength but of different ages, the older receives the greater intensification from new repetitions." For example, if 10 minutes of practice has been followed by a day of rest, the associations derived are much older than those of a person who without break at the close of the first 10 minutes goes on to another period. This is one reason why cramming for examinations does not make for permanence of learning. The interval of rest must not be too long, of course, since the law of disuse begins to operate too forcefully—that is, we forget.

(2*c*) In long periods of work, fatigue sets in. After a certain period of work differing with individuals, additional study has little effect.

(2*d*) High concentration is possible in the short periods, but here again there are marked individual differences. One individual requires a longer warming-up period before he gets down to work and then, if he is of the persevering type, he hates to give up his work. Other students attempt problems with a rush and are soon fatigued, etc.

(2*e*) Further, it is not mere repetition, but the *intention of the learner,* which counts. The most that teachers can get out of this type of experimentation at present is to recognize the general factors involved and *by observation learn to gauge what periods of study and rest in various types of work are most economical for the average student.*

Professor Dearborn illustrated this point by citing a study by the Harvard Medical School of the course in anatomy. This course formerly spread over a period of two years, and a year or more was also devoted to physiology. The student

carried on a number of courses simultaneously over a long period of time. A change in the course in anatomy was then made and it was given in a much more concentrated manner during one year only. The change is generally held to have brought about a great gain in efficiency of learning. In colleges where the quarter system is used, with five hours a week of lectures or class work over twelve weeks, rather than three hours a week of work for 16 or 18 weeks of the usual semester, the opinion is sometimes expressed that the student does not assimilate as much—that the work is too concentrated. An extensive experiment would be necessary, however, to test this opinion. "In some engineering schools," Professor Dearborn said, "I have been told that the student carried from nine to twelve different subjects at one time. Does this not make for distraction, and would not fewer subjects studied more intensively promote efficiency of learning?"

There are many limitations also in any attempted analysis of the law of disuse; or more specifically, of the rate of forgetting. This varies in accordance with the strength of the original learning. There are many things that are so much "over-learned" that our memory will scarcely show any loss. Most of the studies of the rate of forgetting have been made of functions that have been *barely* learned. The usual way of measuring the rate of forgetting is by determining the percentage of time required to relearn after a lapse of time to the point of one accurate recall. Ebbinghaus has shown that the loss of ability is "very rapid at first and then tapers off gradually." Other investigators have found that when functions were learned thoroughly, or until they could be recalled twice in succession, the effects of disuse were not so great. After the first experiment it was found that after twenty-four hours of disuse, two thirds of the original time was required to relearn, whereas in the second experiment, when material was over-learned slightly, only one-third of the original learning time was required to relearn in twenty-four hours.

"Information," Professor Dearborn said, "is seldom overlearned to the extent that skill is. Writing, reading, speaking

are complexes of large numbers of reactions, some of which must be tremendously over-learned before even moderate proficiency is possible in the function as a whole."

The practical problem for the teacher is to consider what things need to be over-learned and what things barely learned, although the student will usually find out for himself what the latter are. Finally, in connection with the law of exercise, Professor Dearborn touched briefly upon "observational learning," where there is little or no chance for repetition. Here is seen in its highest form the importance of the intention to remember. It would be profitable in applying this phase of learning to inquire what a student may get out of the class demonstration of important experiments in physics or out of his own laboratory experiments, the results of which he may observe but once. Some of the most brilliant demonstrations may leave little impress upon the student. He is interested in the manual manipulations, as is shown by the hush that may come over a lecture hall as the professor pauses in his discourse to tie a string around a piece of apparatus. People may be interested in movement per se; therefore a good exercise is to inquire—"what did you see?" "How much did you see?" It might not only be illuminating to a lecturer who has just completed a brilliant demonstration in physics, but also excellent practice for his students, to require that they recall *at the time* what they have seen and let them practice to learn whether they can see more and recall more of the next experiment. There is good ground for believing that students need to practice to increase their skill in observation of the things that it is important that they observe. Let them have a chance not only to observe a good demonstration, but give them opportunity to practice the art of physical observation.

(3) "The third law of learning is the law of effect. It assumes that we learn best those things that give pleasure or satisfaction to the learner, and that we tend to forget experiences which do not, although, of course, certain avoidance reactions may be impressed on the individual by unpleasant

disappointment or painful experiences. There is a good deal of question how this matter works out in physiological terms, but we will note at any rate that successful achievement is one of the greatest incentives to further achievement. Nothing succeeds like success. The practical thing for the teacher is to find out why a given bit of learning or a course of learning does or does not give satisfaction to the learner."

As an illustration of the law of effect, Professor Dearborn discussed a very well known experiment in the rate of learning, in which a student was tested in the rate of learning telegraphy. In this test the graph showing the rate at which messages could be received rose gradually for a period, then the rate of learning tapered off, forming a plateau in the learning graph, after which the rate of receiving again increased. One of the explanations offered for plateaus in the learning graph is that the student has become discouraged and that this discouragement becomes accumulative, which is the converse of the effect of successful performance. Another point is that not enough incentive is brought to bear to have the student rise above mediocrity. Often he believes he has reached his limit and only some emergency or additional incentive makes him aware of his capacity for further development. "Most individuals have hidden reservoirs which are never brought out by the ordinary demands of life. They have gotten into a rut from which some unusual event or course may lift them. Here the rare teacher displays his powers and acts as the stimulator to the student's further response." Professor Dearborn referred to Pavlov in this connection. The hundreds of important researches that have come from his laboratory were due not so much to the fact that he attracted great students to his laboratory as to the fact that he warmed even some of the most mediocre with the fires of his genius.

Another factor pointed out by Professor Dearborn in connection with the experiment on the learning of telegraphy was that there was no plateau in the "sending" graph, possibly because the student there could learn at his own rate. This

suggests that one of the reasons for plateaus in the rate of learning is that the student *cannot set his own pace.* It is set by someone else and he must conform to it. Other examples of plateaus of learning are found to result from the failure to distribute the periods of practice and the intervals between practice to suit the individual's capacity for learning.

Here again the skill of the teacher comes into play. The best he can do at present, as a rule, is to suit the average, and from this arises one of the first justifications for sectioning on the basis of ability. This is the problem of attempting to meet the individual differences of students. Professor Dearborn expressed belief that means of accomplishing this would eventually find their way into the college. The beginnings may already be seen at a number of institutions; as one illustration, in the adoption of the tutorial system and the more recent "reading periods" which may mark the beginnings of the passing not only of the recitation but of the lecture. "At any rate," Professor Dearborn said, "the adoption of this plan has already materially reduced the lecture periods at Harvard."

In conclusion Professor Dearborn pointed out that under each of the above headings we have seen the need for the teacher. In future he is not to be reduced to a person who merely watches the students work; he is going to be of importance because he has learned before-hand some of the things that make for efficiency in learning.

TEACHING THE FUNDAMENTALS OF PHYSICS: MECHANICS

By O. M. Stewart, *Professor of Physics,*

University of Missouri,

July 11, 1928.

"There seems to be a general agreement, outside of departments of physics," Professor Stewart said, "that the

course in general physics is too hard for the average student, often too abstract, with the result that the training given is often superficial." "Students," he said, "strike mechanics first and get lost in a maze of new methods and new concepts." Continuing, he pointed out that it is true that the most important and the most difficult teaching problems in physics are found in mechanics. "We can point out that the chief difficulty is the small time available for each one of the five divisions of the course. But can we not improve our present methods?"

Students have sometimes surprising difficulty in grasping the true meaning of our fundamental concepts. Force, mass, momentum, moment of force, moment of inertia, energy, etc., are for a long time a matter of names, symbols and formulas. One reason, not always appreciated, is that our concepts are more or less artificial. "Even some experienced teachers do not always have clear ideas on these concepts." As an example, it was noted how difficult it is to give a correct and clear definition of *force,* or of *mass.* "We ourselves do not always use the term *force* consistently. We talk about 'lines of force' when there is no force. We often use the term centrifugal force incorrectly. We may incorrectly call the product *ma,* a force or reaction." There is a difference in our understanding of the concept of mass. A definition that mass is quantity of matter means nothing unless the method of measuring is specified. "Quantity of matter" may be measured by (1) volume of commodity; (2) by area, as in case of dry goods; (3) by numbers, for example, eggs are sold by the dozen; (4) by earth-pull (weight); (5) by "beam-balance" method; (6) by inertia. Many physicists today restrict the term *mass* to the last one. "We must appreciate fully," Professor Stewart said, "the difficulties involved in understanding our various concepts. Under the circumstances, we should teach the simplest concepts first and reserve the hardest until later in the course." Some think that a few, for example, *mass,* might be omitted entirely.

To meet the objection that our teaching is as "dry as dust,"

Professor Stewart said that we must do all we can to enliven it. The best solution is usually the use of many simple practical applications. "In general, if you cannot find a specific application of a topic, better omit the topic."

One of our difficulties is the large number of systems of units. "We could save time and decrease difficulties by using fewer systems." The use of unknown, never-used units is responsible for much dullness and confusion. If the student is to form definite and specific ideas quickly, he should begin with familiar units. A greater use of practical units could well be made without any loss in knowledge or clear thinking on the part of the student. As many as five different systems of units in mechanics are found in some textbooks. Two are all we need. "Why not limit ourselves to the C. G. S. and the British Engineering systems? This would mean dropping the British Absolute system."

"Where the time available for teaching physics is limited, it would be better to decrease the number of topics and cover with greater thoroughness a more limited field. Avoid superficial work even if the field is greatly narrowed. Much can be gained in all our courses by omitting non-essential parts and side issues. Avoid distracting details. Things which will not be needed later, and things which the average student does not grasp should be omitted."

In conclusion, Professor Stewart presented the following summary of suggestions of ways to make topics in mechanics easier to learn:

Avoid generalizations or definitions until specific examples are understood.

Use many applications of all generalizations to familiar experiences.

Insist on proper use of technical terms.

Have frequent (daily) reviews of fundamental principles.

Begin with simplest concept (force). Postpone harder concepts.

Use familiar units.

Omit non-essentials.

In the discussion of any topic begin with specific cases, generalize, then end with other specific cases.

TEACHING THE FUNDAMENTALS OF PHYSICS: HEAT

A. W. DUFF, July 12, 1928

"Heat is comparatively easy to teach," said Professor Duff, "because of the abundance of familiar illustrations." These, he thinks, should be utilized to the utmost, but without going into engineering applications, such as the mechanism of the steam engine, because what is gained in interest by so doing is lost in efficiency. Questions which students ask on such matters should usually be answered very briefly or outside of class.

Meteorology provides numerous illustrations of the behavior of gases and vapors; the physics teacher can profit by looking over such a book as Humphrey's "Physics of the Air."

Certain general principles are useful in tying things together. The conservation of energy should be emphasized for this purpose. It should also be employed to fix this important principle more firmly in the student's mind in connection with mixtures, fusion, vaporization and—an important matter—the two specific heats of gases. The difference between these two specific heats should be explained in terms of work and energy. Radiation is an illustration of both the conservation and of the transformation of energy.

"It is desirable to give an idea of the nature of heat at the very beginning," Professor Duff said, "for then we can appeal to the law of the conservation of energy and other fundamental principles in the later work, and students are stimulated to more fruitful thinking."

It is probably better to define temperature from the beginning in terms of the international standard, the nitrogen thermometer. If it is defined in terms of the mercury thermometer until expansion of gases has been studied, the better

students get the feeling that temperature has no definite meaning. But the definition, once stated, "need not be rubbed in;" it should be pointed out that a good mercury thermometer agrees closely with the other.

When the expansion of solids and liquids is studied, it is well to dwell on the coefficient of expansion

$$\frac{L - L_0}{L_0 t} = a$$

and on the definite ideas involved in it, because this will help with other similar coefficients studied later. The subject of expansion is simple to illustrate, and easy to teach.

Professor Duff believes it is necessary to teach the calorie as well as the British thermal unit, because the former is involved in the computation of I^2Rt losses and because it is universally used in the statement of physical results. The difficulty as to two sets of units that occurs in mechanics does not enter here, because the two are exactly parallel. The use of the pound as the unit of mass need not create any difficulty; in this we need not try to be too logical.

(In reply to a question, Professor Duff said he thought some reference to the kilogram-calorie also advisable.)

As to fundamental laws: The law of conduction may well be put in the Fourier form, because this applies to so many other phenomena. Its statement in the form "Flow is proportional to temperature gradient" should be rubbed in before going further, and it should finally be left in the form

$$\frac{H}{AT} = \frac{K^{t_1 - t_2}}{d}.$$

"How much should be taught under radiation and absorption?" First, of course, the elements of the subject. Then the concept of the black-body (preferably written with a hyphen and pronounced *black'-body* to avoid confusion with the ordinary sense) is useful. "Like the concept of a perfect circle it is abstract but nevertheless valuable, because by reasoning about it we obtain conclusions which give us

approximate information about actual bodies." Stefan's law is not difficult and should be included, and Newton's approximate law of cooling is needed for calorimetric corrections and by the engineer.

Under fusion and vaporization, the critical point should be included, because it is instructive and fundamental and a beautiful experiment is available to illustrate it.

It is debatable just what topics should be taught in addition to the fundamental ideas about heat and work. Inclusion of adiabatic processes is necessary because of the application to sound. The topic should be treated lightly, however, and the formulas can if necessary be accepted without proof:

$$pv^k = \text{constant}$$
$$(\text{adiabatic elasticity}) = k\ (\text{isothermal elasticity})$$
$$(E_a = kE_{is})$$

It is worth while to convey an idea, without giving details, about absolute temperature on the thermodynamic scale. This necessitates the introduction of the perfect reversible cycle of operations, but the mathematical proof should be omitted, for students in general fail to get the idea of it. In general, more mathematics should not be used in teaching physics than is necessary for clear and logical reasoning. The difficulty is in following the ideas parallel to the symbols; reasoning in ordinary language, when possible, is better than reasoning in symbols. The symbols can be introduced afterwards if time permits.

In response to a suggestion, Professor Duff undertook a demonstration of a method of teaching a definite topic, in the general field of heat, selecting the gas law for the purpose. Of this no *verbatim* report was taken, and an outline would be unsatisfactory.

TEACHING THE FUNDAMENTALS OF PHYSICS: ELECTRICITY AND MAGNETISM

W. S. FRANKLIN, July 13, 1928

Professor Franklin said that he has for many years departed from the historical point of view in presenting the analytical elements of electricity and magnetism to sophomore students and that his method is so fully developed in the latest edition of Franklin and MacNutt's *Electricity and Magnetism* that he would refer his auditors to it frequently. (In the following paragraphs this text is referred to as *E. and M.*)

"I begin with electric-current phenomena," Professor Franklin said, "and proceed without a break to the consideration of the condenser and thence to the general subject of electrostatics, using always the units of the electromagnetic system and the closely related units of the ohm-ampere-volt system."

General effects of the electric current. In speaking of the general effects of the electric current (magnetic effect, chemical effect, and heating effect), Professor Franklin always includes a brief reference to what may be called *gap effects.* "Surely the effects that are produced in the gap of an open circuit when a momentary current flows in the circuit can properly be spoken of in a general way as an effect of the current." (See pages 5 and 6, *E. and M.*)

Simple Circuit Problems. One of the most important fundamental facts is that a steady electric current flows only in a closed circuit. "I make early use of the electron conception of the electric current to visualize the necessity of a closed circuit," said Professor Franklin (see pages 6, 7, and 8, *E. and M.*), "and I always begin my problem work with circuit problems." (See pages 15 to 17, *E. and M.*)

Electrolysis. Professor Franklin said that he considers only the simplest facts and laws of electrolysis and gives no problems in this division of the subject. Pages 18 to 29, *E. and M.*, somewhat more than cover the subject as he gives

it to sophomores. He makes use, however, of the International Standard Ampere, and defers the magnetic definition of the ampere to a much later section. He also ties up the voltaic cell with the electrolytic cell by a brief consideration of energy relations. (See page 21, *E. and M.*)

Definition of Resistance. "Standing on the International Standard Ampere, one is ready to consider Joule's law and the definition of resistance." This is outlined on pages 37 to 45, *E. and M.*

Definition of Potential Difference. "The only way for the beginner to get a concrete idea of potential difference," said Professor Franklin, "is from the point of view of electrostatics; and at this point I frankly draw upon what the high school has given the students concerning electric charge and electrostatic attraction and repulsion, and develop the idea of potential difference, making use of the electron conception of the electric current." (See pages 45 to 46, *E. and M.*)

Ohm's Law. Ohm's law and Joule's law are completely equivalent (see page 48, *E. and M.*), and at this point Professor Franklin derives Ohm's law from Joule's law and the definition of potential difference. One great advantage of this, he pointed out, is that the conditions under which Ohm's law is true are clearly recognized. (See page 46, *E. and M.*)

The Energy Equation ($P = EI$), Joule's Law and Ohm's Law Are Nearly Always Applied to a Portion Only of a Circuit. A clear recognition of this fact is of the utmost importance. (See page 50, *E. and M.*). At this point, Professor Franklin develops and applies the ideas of electromotive force, current and resistance in the usual way. (See pages 50 to 70, *E. and M.*)

Induced E.M.F. "A discussion of induced e.m.f.," Professor Franklin said, "requires some understanding of magnetic field and of magnetic field strength, and I develop the necessary quantitative ideas on the basis of the International Standard Ampere, making use of the equation of side-push, $F = HLI$." (See pages 73 to 79, *E. and M.*) The classical

development is left until a later time. (Pages 207 to 220, (*E. and M.*)

The foundation of the quantitative discussion of induced electromotive force was discovered and formulated by Helmholtz, and Professor Franklin calls this *Helmholtz's Principle.* (Pages 71 and 72, *E. and M.*) On the basis of this principle he develops the quantitative aspects of induced e.m.f. in the usual manner. (Pages 80 to 83, *E. and M.*) "The equations of induced e.m.f. as arrived at in the above development," Professor Franklin said, "are highly abstract, and I believe it to be of the utmost importance to apply these equations to the direct-current dynamo (pages 83 to 86, *E. and M.*), and to the transformer and the induction coil." (See pages 94 to 97, *E. and M.*, especially problems 73, 74, 76 and 77 on pages 103 and 104.)

Inductance. "There is a curious persistence among teachers of an old-fashioned point of view which attempts to make use of the idea of the 'extra current' in the discussion of inductance. There is another persistent over-emphasis on self-induced e.m.f." The former Professor Franklin avoids completely, and self-induced e.m.f. he relegates to a subordinate rôle. An e.m.f. E, in excess of what is required to overcome resistance, acts on a circuit. "What is the effect?" Professor Franklin asked. "It causes the current to grow at a rate proportional to E and the proportionality factor is the inductance L of the circuit, so that $E = L(di/dt)$." A force F, in excess of what is required to overcome the resistance of the water, acts on a boat. "What is the effect? It causes the velocity of the boat to increase at a rate proportional to F and the proportionality factor is the mass m of the boat, so that $F = m(dv/dt)$. The inertia reaction of the boat is, of course, equal to $-m(dv/dt)$, the 'inertia reaction' of the growing current in a circuit is $-L(di/dt)$, and this 'inertia reaction' is called the self-induced e.m.f. To place the chief emphasis on $-L(di/dt)$ is just as misleading as to place the chief emphasis on the inertia reaction of an accelerating boat; forgetting the cause of the acceleration which is the external applied force!"

There is, however, one aspect of self-induced e.m.f., pointed out by Professor Franklin, which brings it more clearly into consideration than the inertia reaction of a boat. "The self-induced e.m.f. can be *seen*, as it were, in the growing magnetic flux due to the growing current."

The discussion of inductance (pages 104 to 109, *E. and M.*) was pointed out as worthy of attention inasmuch as it does not involve the usual fallacy of an exaggerated emphasis on self-induced e.m.f.

Electric Charge and the Condenser. Professor Franklin uses the idea of electric charge and the facts of electrostatic attraction and repulsion in connection with the discussion and use of the electron conception of the electric current (Pages 7 and 45, *E. and M.*). This leads to a more analytical consideration of the idea of electric charge in its relation to current, which in turn leads to a complete formulation of the laws of electrostatic attraction. "It seems to me," he said, "the most important thing to do at this point is to develop a sense of feeling of what may be called the 'electrical elasticity' of a condenser. This is done on pages 112 to 115, *E. and M.*, and the usual development follows on pages 116 to 122."

The capitance C of a condenser is proportional to ka/x, where k is the inductivity of the dielectric, a is the area of the dielectric, and x is the thickness of the dielectric. Therefore, we may write

$$C = B(ka/x),$$

where B is the proportionality factor. The factor B is a constant whose value must be determined by experiment and we should not be blind to this fact, because "when c.g.s. electromagnetic units are used, B is equal to $(\pi/4)V^2$, where V is the velocity of light." Continuing this discussion, Professor Franklin said, "No, B is an experimentally determined constant, and it is not only permissible but it is highly desirable to accept it as such and develop our subject on the basis of experiment! One can point out numerous steps in the usual development of the fundamentals of electricity and magnetism

where the 'compelling force' of experiment is lost sight of."

"I use the above equation," he said, "and the equation of the condenser $q = CE$ as the basis on which the whole of the elementary analytical theory of what is ordinarily called *Electrostatics* is based." (See pages 127 to 174, *E. and M.*)

Professor Franklin does not use the electron theory to explain the phenomena of electrostatic induction because these phenomena do not seem to be of sufficient importance to warrant a more complete discussion.

The Electron Theory. Electric discharge through partial or very high vacuua is today of very great interest and importance and no sophomore course, in Professor Franklin's opinion, would be complete which did not include a fairly full discussion of the subject. It is outlined in pages 178 to 206 of *E. and M.*

The Classical or Historical Point of View Concerning Electrostatic and Magnetic Systems of Units. "I am sorry to be obliged to admit," Professor Franklin said, "that a student must at present familiarize himself with the units of the c.g.s. electrostatic system because these units are still widely used, but it is unquestionably a mistake to suppose that any physical phenomenon of any kind can be more easily understood in terms of c.g.s. electrostatic units than in terms of c.g.s. electromagnetic units. One might as reasonably claim that geometry is easier in French than in English."

Professor Franklin feels that it is wholly unnecessary to use two systems of electrical and magnetic units and the sooner the units of the electrostatic system are outlawed the better. "Of course," he said, "to outlaw these units will be hard on men who have gotten into the habit of using them." He, himself, has gotten into the habit of using electromagnetic c.g.s. units or the units of the ohm-ampere-volt system for everything. He has found it an easy habit to form and to follow.

A Little-Appreciated Experiment in Electrostatic Induction. In concluding his remarks, Professor Franklin referred

to the experiment with the electric-doubler (pages 155 to 158, *E. and M.*) as one of the most important and strikingly interesting of all electrostatic experiments.

TEACHING THE FUNDAMENTALS OF PHYSICS: LIGHT AND SOUND

O. M. STEWART, July 16, 1928

Professor Stewart began his remarks by saying that the teacher has greater freedom in choosing the topics to be included in the study of light and sound, as contrasted with mechanics, heat and electricity, in which there are more definite restrictions because of the needs of students in their subsequent engineering courses. But here, as elsewhere, it is nevertheless necessary to keep in mind the aims of the course and the ability of the student. It is also necessary to follow the order and methods of the text book reasonably well. The selection of the text book is usually based on the way mechanics, heat and electricity are treated and consequently the teacher sometimes finds himself not in agreement with the method of handling light and sound. This may cause him to depart from the methods used in the text, a practice which does not always lead to good results. Nevertheless, Professor Stewart believes that the teacher may exercise some freedom in the selection of his material.

From this general introduction Professor Stewart proceeded to the methods of dealing with light and sound. "Wave motion," he said, "is usually introduced at the beginning of the subject of sound. It is not advisable to teach the entire subject of wave motion as an isolated one; it should not be isolated completely from its applications in sound and light and if such topics as refraction and interference are explained under wave motion the study of them should be repeated in connection with their applications." Nevertheless, in Professor Stewart's opinion, there are many facts about waves that are simple enough to be taught separately. The

discussion of waves should not be restricted to trains of waves. Most cases of wave motion met outside of the textbook are of the pulse type. "The study of wave motion," he said, "is of great importance today and engineers handle many problems from that standpoint. For example, we are beginning to hear of wave filters to absorb mechanical waves and of mechanical impedance bridges being used in certain measurements." Professor Stewart then touched upon the matter of arousing the interest of students in the study of light and sound and mentioned as an illustration the fact that since so many engineers are giving a great deal of attention to sound, for example those in the Bell Telephone Laboratories, it is easy to arouse interest in the subject.

He feels that emphasis should be placed on the analysis of sounds and on the relations between the fundamental tone and the overtones. Students should understand what is meant by distortion and why a linear characteristic of the sound reproducing machine is desirable. Time given to musical scales and musical instruments should, however, be cut to a minimum.

Professor Stewart then spoke of the matter of demonstration experiments in connection with light and mentioned that there are unusual opportunities in the way of fine demonstrations. This again is a means of arousing the interest of the students. A special effort should be made to have the students see all of the important phenomena and it is therefore worth while to set up apparatus in a corner of the laboratory so that the student may see for himself such things as interference fringes, polarization phenomena, and the like, and not merely witness them at long range in the lecture room.

Professor Stewart believes, in general, that physical principles, rather than geometric relationships, should dominate the work on light. As an example, he believes that the index of refraction should be first defined as a ratio of velocities rather than as a ratio of sines. However, both the ray method and the wave method should be used. The ray method should be used in the discussion of optical instruments and in many

other cases, because of its relative simplicity. He added a word of caution in this connection, saying that ray diagrams are sometimes misleading. For example, when the passage of white light through a prism is shown by a diagram, the student may think that red light goes through one part of the prism and blue light through another. The sine law should be written

$$n \sin i = n_2 \sin i_2,$$

where the sub-script *1* refers to one medium and the sub-script *2* to the other.

In image formation, Professor Stewart starts by giving the important facts first; the laws of position and size are developed only after the facts are known. He feels that too much time is often given in the classroom and laboratory to spherical mirrors, because the applications of such mirrors are few. It is better, he believes, to spend more time on lenses. It is advisable to use the same form of law, with the same rule for signs in all kinds of mirrors, and lenses. In connection with lenses and mirrors, graphical relations should be emphasized. In the treatment of lenses it is better to deal with thin lenses.

The spectrum and its applications should be treated in a descriptive and experimental way, Professor Stewart believes. Ancient and disputed theories of color vision should be omitted.

Throughout the topic of light, and especially in connection with interference of light, Professor Stewart believes it is inadvisable to talk about things that are not demonstrated to the students. If the experiment cannot be shown in the lecture room, it should be shown to the students in the museum or in the laboratory.

Professor Stewart then exemplified a method of presenting a particular subject in the field of light and sound, and dealt with the diffraction grating. First, a general description of the phenomena observed when white light is used was given. This was accompanied by a demonstration. Then, the effects of using gratings with different numbers of lines per centimeter

was shown experimentally. This was followed by the theory of the grating, following the usual ray method. Next was given an explanation based on the use of Huygens' wavelets. He explained that in this case a double approach to the theory is advantageous. Throughout the demonstration he explained that facts are given first, accompanied by demonstrations, and the theory later.

After the demonstration, Professor Stewart stated, that in his opinion diffraction and polarization should also be treated from a descriptive and experimental viewpoint and that their bearing on the wave theory of light should be given. He believes that X-ray spectra should be included in this part of the subject.

While the wave theory is adequate for all elementary purposes, Professor Stewart believes that some explanation of the quantum theory should be given. In this connection no trouble is encountered until one goes into the theory of the emission or absorption of energy by an electron.

Professor Stewart concluded his remarks by speaking of the richness of the history of physics and said that historical reference often stimulates interest and gives better perspective for the study of the subject. In this connection the history of the development of the study of light is especially valuable.

THE LECTURE, CLASS-DISCUSSION, AND LABORATORY IN PHYSICS COURSES

A. W. Duff, July 13, 1928

Professor Duff began the discussion of the above topic by outlining the purpose of the three types of class exercises.

"The purposes of a *lecture,*" he said, "are (*a*) to stimulate interest in the subject, and (*b*) to illustrate fundamental concepts and principles by experiments. To that end the apparatus should be simple and the lecturer should give a clear-cut account of what he is endeavoring to do and of the mean-

ing of the concept which he intends to illustrate. He need not be too formal; an occasional laugh will relieve the strain of formality. He should refer to interesting points in the history of the subject to some extent, as this tends to arouse interest. He should avoid mere repetition of the text book."

The *recitation* (a better term would be *class-discussion*) should reinforce the lecture and clear up difficulties, but it is not successful unless the students are stimulated to ask about as many questions as the instructor asks.

"The purposes of the laboratory," Professor Duff said, "are (1) to produce concrete thinking about important concepts and principles and (2) to give the student some knowledge of precise measurements. It supplies the element of personal experience in which the lecture and recitation are deficient."

All three forms of exercises—lectures, recitations and laboratory periods, are needed completely to "put across" the ideas of physics. Lectures alone are not sufficient. Bad lectures—complicated and involved demonstrations—are worse than no lectures— they may even tend to confuse the student. The instructor should make careful preparation for both lectures and recitations.

A point mentioned by Professor Duff as of importance in dealing with students is the giving of instruction in "How to study." This may be done informally in the regular class periods—those provided for recitations—but some more formal instruction by a competent authority is useful.

In concluding his introductory remarks, Professor Duff spoke briefly of the function of the lecture, mentioning that the lecture is a desirable teaching medium in physics, provided the lecturer is competent. With large classes the demonstration lecture is an efficient means of instruction. With small classes it may well be replaced by the "demonstration-recitation." One or two precautions in lecturing were mentioned: (1) Do not try to cover too much ground, (2) do not, in general, attempt quantitative demonstrations.

THE LECTURE AS A TEACHING MEDIUM

By Sir John Adams, *Professor of Education,*

University of London,
July 13, 1928.

Sir John Adams delivered his talk on lecturing as a medium of teaching as a contribution to the general discussion of teaching methods.

"Bad lecturing," he said, "is the worst form of teaching. The lecture saves time, however, by getting to the point and can be given to groups; hence it is valuable. The teacher is often criticized," he said, "because he talks too much and occupies too much of the student's time. The lecture should not be uni-polar, however, but should be bi-polar, and the audience should be made to do as much thinking and as much work as the lecturer, if not, indeed, more, since the lecturer is prepared and is familiar with his subject and the audience is not."

Taking this as a premise, Sir John passed to the process of listening as contrasted to that of speaking, and said that listening is a rythmic process, not a constant one; it is a succession of concentration beats and diffusion beats. The concentration beat is valuable in gathering material but the diffusion beat is necessary for absorbing it, hence both beats of listening are important. "It is much easier," he said, "to talk logically than to listen logically—that is, to keep the thread of the discourse straight as it is delivered by the speaker. It is possible for students to become professional listeners and to become adept at appearing to listen without comprehending what is said."

Dante has said, "He listens to good purpose who takes note." In connection with this matter of the effort made by the listener at a lecture, Sir John spoke of the matter of note-taking. "There are four forms in which notes may be taken," he said:

(*a*) Verbatim. This, he believes, is never worthwhile, because it either leads to a voluminous mass of material that

cannot be easily digested or it may mean that the lecture is a poor one and might better be presented in written form.

(*b*) Catch-as-catch-can note-taking. Such notes give disconnected ideas and hence are of very little value.

(*c*) The topical method. In this method the topics as indicated by the speaker are arranged systematically but are not amplified to any great extent.

(*d*) The "listening" type of notes. When notes are prepared in this way the lecturer is listened to and what he says is summarized at the same time and almost unconsciously. This method of note-taking requires much practice and must be developed. It is, however, the most valuable method.

Following his discussion of the lecture, Sir John touched briefly on the matter of the laboratory as a teaching medium and said that its chief value is that people work with ungloved hands and actually learn through contact with the apparatus or mechanisms handled. He mentioned that kid gloves are an almost perfect insulator against the acquirement of knowledge and concluded that the majority of people learn best through sight and the minority best through hearing. The combination of sight and hearing undoubtedly furnishes the best medium of acquiring knowledge, and this should be supplemented by the laboratory, in which the student actually handles the equipment.

THE FUNCTION OF LABORATORY WORK IN PHYSICS COURSES

A. W. Duff, July 16, 1928

Professor Duff introduced his lecture with a short history of the physical laboratory. The idea of the physics laboratory seems to be due to Lord Kelvin who recognized the necessity of having students perform experiments themselves rather than always merely sitting as observers. It has been only within the last fifty or sixty years that engineering colleges in the United States have introduced laboratory courses in conjunction with work in physics.

Professor Duff then explained the function of laboratory exercises. These he classified under three main heads:

(1) The teaching of concepts and principles;
(2) Imparting knowledge of and familiarity with methods and instruments; and
(3) Imparting the scientific spirit of accuracy in
    (*a*) drawing conclusions,
    (*b*) criticising results, and
    (*c*) writing reports.

An illustration of the content of laboratory courses in physics was given by Professor Duff who wrote out the titles of the experiments which are required in two undergraduate courses in physics at Worcester Polytechnic Institute. The first course is given to the sophomore class; the experiments comprised in it are primarily on "Concepts and Principles." The apparatus is simple and all students in a section work "abreast." Each exercise is a problem to be solved experimentally and also by calculation. The other course is given to the junior class and deals with "Concepts and Measurements." In the former, no high degree of accuracy is required and the reports are written in class. The experiments are discussed in the recitation periods and explanations are also given, as needed, in the laboratory. Students are encouraged to use logarithms in their computations; practice is also given in the use of powers of 10. In this course the usual type of experiments is given, *e.g.*, coplanar and concurrent forces, velocity and acceleration, moment of inertia, centrifugal force and the like. In the second course, that of combined objectives, the aim is not accuracy alone. Here the students work partly "abreast" and partly "in series." Considerable accuracy is required, but no exercise is given merely for accuracy of measurement. Such experiments as vapor pressure determinations, heat of vaporization, and tests with optical pyrometers may be of low accuracy but nevertheless very instructive; many interesting questions can be brought up in connection with them. Experiments entailing a high degree

of accuracy in manipulation and results, such as the measurement of the wave length of sodium light, are often lacking in instructional value, but this can be avoided by adding some qualitative experiments on spectra in general.

Experiments having to do with elasticity and strengths of material can best be left to the engineering departments and not included in the physics course; there is danger of giving too many exercises on stretch modulus, shear modulus, calibration of weights and the like, sometimes because apparatus is available or reports are easily examined.

Students should work individually in the laboratory when possible but there should be careful group discussion. It is also advisable for the instructor to be available for conference hours with students. Reports should be clearly written and should show that the student has a clear comprehension of the experiment.

LECTURE-DEMONSTRATIONS IN TEACHING PHYSICS

A. W. DUFF, July 20, 1928

In explanation of the demonstrations which he would show during the hour, Professor Duff said that he had been urged to go through the entire demonstrations even though the experiments were well known to teachers of physics. Detailed explanations would be omitted, however, in view of the experience of the group.

Before commencing the demonstrations, Professor Duff outlined the desirable qualities that experiments shown in the lecture room should possess:

Apparatus should be simple.
Apparatus should be on a sufficiently large scale so as to be easily seen by all.
In general, only one principle should be shown by any one demonstration.
Demonstrations should stimulate thought.
The pace should be neither too slow nor too rapid.

Positive effects are better than null effects.
Avoid spectacular effects, although an occasional dramatic element adds zest.
The lecturer should succeed in his experiments.

He also gave the following informal hints:

Rehearse thoroughly in all details.
Beware of sudden impulses to change the experiment.
Explain clearly but briefly.
Keep thinking of the class.
Never "cook" an experiment.
Beware of long pauses.
Never apologize for an experiment in advance.
If you fail, don't scowl!

Each of these points was commented upon, the following being a brief digest of the remarks:

Increasing the complexity of the apparatus and polishing parts unnecessarily distracts the student's attention from the main point of the demonstration. This point was well illustrated by the apparatus shown, the unimportant parts of which were painted a dead black.

It is important to have all demonstration apparatus of sufficient size, and it is well for the lecturer to test this visibility in advance by walking to remote parts of the lecture room. Insufficient size is one of the commonest faults of demonstration apparatus furnished by equipment and instrument makers.

Confusion is almost certain to result if more than a single principle is attempted in any given demonstration. In advanced demonstration this, of course, may be modified as occasion demands.

Demonstrations, for the best effect, should stimulate thought, especially self-inquiry. Sometimes it is advisable so to present the demonstration as to leave some part of the explanation incomplete, so that the student must arrive at his own conclusion either alone or in discussion with other students outside the classroom.

The pace of the demonstration must be neither too slow nor too rapid. It can best be timed by experience and by

noting the students' reactions. A too rapid demonstration is over before the majority of the students start to think, while in a too slow demonstration the student arrives at his conclusion first and his attention then wanders. It is like the telling of a good story.

Positive effects should be striven for. An experiment makes more impression upon the class when there is some visible reaction connected with the proof than does one which gives no visible action or motion as a proof.

Always keep in mind that the main function of the demonstration is to be instructive. Hence, avoid the spectacular, as a rule, although an occasional dramatic element adds zest and enlivens interest. Tait was such a lecturer and demonstrator, while in contrast Kundt's demonstrations were too elaborate and involved.

The experiment should be so organized and the apparatus so tested that the failures are reduced to a minimum; "we might say, the lecturer must be infallible." The example of Tait's demonstrations and the aid given by his well trained assistant were here mentioned. All preparations must be made in advance and sudden changes in mode of presentation should be avoided. They are likely to be confusing and unsuccessful.

The lecturer, to be successful, must not only keep in mind these things, but he must rehearse his experiments with great care before the actual presentation before the class. Rehearse! Rehearse!

Explanations must be given clearly and deliberately either before or during the experiment, not afterward. While the experiment is being performed and the explanation being given, the lecturer must always be thinking of his class. To neglect this frequently causes embarrassing situations, due sometimes to statements of double meaning.

Never apologize in advance for an experiment which may go wrong. If such seems to be necessary, by all means omit the demonstration. In addition to this, it is needless to say that a good lecturer never "cooks" an experiment in order

to get the desired result. The students will usually detect the fake, but even if they did not, the lecturer will commence to lose faith in himself.

"Long silences are stumbling blocks," said Professor Duff. He then told of an incident when, during a rather long silence, his assistant was the only one in the room occupied since he was turning the crank of an air compressor. A student started to whistle "Everybody works but father."

After these introductory remarks, Professor Duff showed ten lecture-experiments covering a considerable range of topics and selected to demonstrate both good and bad points of such work as indicated by the foregoing "rules" and "cautions." The members of the group were asked to rate each test, using *10* as a perfect and *0* as the lowest score, arbitrarily taking the first test, the demonstration of Hooke's law, as a criterion and giving it a rating of 5. The following tabulation lists the experiments and gives the average scores assigned by members of the group.

a. Hooke's law experiment	5.0
b. Surface tension of liquids	7.0
c. Effect of pressure on melting point	7.8
d. Thermal conductivity of gases	6.5
e. Electrostatic attraction and repulsion	5.4
f. Curie point in magnetism	9.2
g. Electrolytes and non-electrolytes	7.5
h. Interference of light (soap film)	7.5
i. Scattering of light (sunset)	8.5
j. Transformation of heat into mechanical energy	8.3

Professor Duff stated that during the course of a year's demonstrations he performs approximately four hundred experiments, of which not more than one per cent fail. He realizes that students sometimes "learn by failure," but is of the opinion that if two or three percent of the demonstrations are failures the students lose respect for the lecturer and for the course. Self-control, a sense of humor and some knowledge of practical psychology are essential for successful lecturing.

THE CLASS-DISCUSSION METHOD IN PHYSICS

O. M. STEWART AND W. F. DEARBORN, July 20, 1928.

Professor Stewart began the discussion by stating the following "rules" which may be followed in reference to class-discussions:

1. Start promptly.
2. Be informal.
3. Review at the beginning of the hour.
4. Give everyone an opportunity to ask questions.
5. Do not waste time on topics which students should get unaided.
6. Stick to the subject.
7. Do not use the classroom as a "coaching" place.
8. Follow the general plan of the textbook except where a double approach is desirable.
9. Do not use a method of teaching which does not demand the attention of all.
10. Prepare for each lesson.

Professor Stewart said that he had formulated these rules to take care of situations in his own experience. He said that lesson and problem assignments are made at the beginning of the semester. Preparation is made for a class-discussion by reading the lesson through and making a list of topics covered. The more important are marked. Additional and specific applications of the different topics to be discussed should be sought. He begins the class discussion by asking for questions in review. If none are asked, he asks some himself.

Some time may be spent on discussing difficulties students have had with problems. The rest of the hour is given to the lesson assigned for that day. Discussions are usually started by questions. If the students do not start it, the teacher does. A skillful use of questions is one of the most valuable assets of a teacher. Questions should always have some aim or motive.

In answer to a question Professor Stewart stated that after asking a question he does not leave it until an answer is obtained.

Students are not sent to the board in his classes because he has found that he cannot keep all of them busy; too much time is wasted. Some teachers, however, seem to do this more successfully. If the discussion seems to be dragging, Professor Stewart believes it is advisable in some way to change the method of attack. He does not ask questions on all topics, but picks out the more important or ones which appear likely to cause difficulty.

In answer to a question, Professor Stewart stated that in the class-discussion hours he prefers diagrams put on the board by the instructor, even if poorly drawn, to the use of lantern slides.

He believes that there should be weekly staff meetings and that only regular, full-time members of the staff should conduct class-discussions.

In answer to questions, Professor Stewart stated that he does not use the brief daily written test, but has a full hour for written tests once every two weeks. He believes that students prepare for their recitations. He also made the statement that he stands when conducting a discussion period in order to keep things moving faster.

* * *

Professor Dearborn's first point was that we might accept as a fact that there has been a "passing of the recitation," as such, in the better class room practice. The effort to catechize each student in some random order, in order to set down a daily mark on his recitation is rapidly becoming a thing of the past. If the effort is to see that each student is called, questioning often degenerates to a catch-as-catch-can basis. If only a few students are examined rigorously, some are likely to take a chance that they will not be called upon; others are bored at the ill preparation of some of their classmates; and if the abler students are thoroughly examined and pressed to their limit, much of the discussion is likely to be over the heads of the ill prepared.

The recitation as a testing method Professor Dearborn be-

lieves is seldom successful or pedagogically sound. The testing phase of class work had better be isolated as a separate function and done by group response, that is, by a short written test. The new type of examination facilitates this purpose; it can certainly well supplement the essay type of examination, if not replace it entirely in the daily test.

Professor Dearborn then took up the matter of the use of textbooks. It is also a passing practice, he said, to use the textbook as if it were the written word of God, and so assigned by teachers and read by students "a few verses at a time."

He pointed out that the method employed in the school as an influence on the mentality of students is worth noting. Under the German method of instruction, mainly by lectures and oral group drill, "pupils become trained, attentive listeners and are able in answering questions to talk coherently for long periods, imitating the continuous discourse of the teacher." *

Professor Dearborn pointed out the disadvantages of the oral method of presentation as: (1) the partial presentation of some subjects due to the limitations of the teacher's interest and training, and (2) that students cultivate little independence of thought or opinion. The student is likely to be too greatly impressed by the teacher's authority.

"It has been thought," he said, "that one of the social advantages of emphasis on reading in American education was the possibility of cultivating independence of thought through wide reading, but textbooks are more often of such a character and so used as to lose this possible advantage, because: (*a*) The textbook often presents the individual point of view of the author. (*b*) It is too often accepted as final authority." In support of the latter point, Professor Dearborn noted the readiness with which people in general are likely to accept as truth anything that is printed.

Professor Dearborn believes in the use of the textbook naturally like any other book. While there may be some excuse for "gnawing through it" at the rate of a few para-

* Referring to Judd, *Introduction to the Scientific Study of Education*, pp. 15–16.

graphs or pages a day in the case of some subjects, such as mathematics, and possibly physics, where there are a host of more or less independent problems to be solved, nevertheless, the advantage of choosing a more discursive text where technical information is not so concentrated, and where it is more diluted with supplementary material should be noted. He believes that the student should be advised to read a whole chapter or section of the book through once rapidly on the first reading, so as to get a perspective of the subject, and in order to learn what he already knows about it, and so that particular places and subjects can be marked, which are difficult to understand without further study or explanation. The student and instructor may then compare notes and these places may be explained and reinforced.

If the textbook has a table of contents and index, the student may be reminded that these may serve a useful purpose in surveying the subject.

As to the use of the textbook in class, Professor Dearborn believes that the textbook should be kept open. The order of topics of the chosen textbook should be followed and the text material integrated with lectures by distributing mimeographed study guides, including lists of text questions on both.

Professor Dearborn suggested that it might be a valuable practice to have students make in class systematic reports on topics which need explanation over the textbook discussion, and which are purposely held out of the lectures.

Discussing the matter of reviews, Professor Dearborn said that we should distinguish between reviews and drill. Drill involves repetitions to insure permanent retention of principles, laws and methods. Review, on the other hand, is for the purpose of:

(1) Fixing the most important points in mind by first selecting and emphasizing the most important things in the assignments.
(2) The selective recall of known material as the basis for new lessons.
(3) For pointing out weak places in the student's learning.

(4) As an effective demonstration and motivation of the desirability of the student's practicing himself in "self-review."

Professor Dearborn pointed out in the matter of review the relationship to the law of forgetting discussed at a previous lecture, and pointed out that a few minutes of review within a day or two after the material had been studied, pays big returns. The review also has the advantage of teaching the student how to acquire a good deal of information intensively and reinforces his knowledge by what he has previously learned.

SECTIONING ON THE BASIS OF ABILITY

By W. F. Dearborn, July 26, 1928

Professor Dearborn began his discourse by a discussion of the extent of individual differences. "Objective tests," he said, "have not discovered this completely, but they have given a more exact description of the *range* of individual differences, and thus are of value."

He then gave numerous examples of the range of individual differences and particularly of the overlapping of abilities in the various age-groups of students. The examples were chosen from the field of primary and secondary education, but the same general conditions apply to more advanced students.

"The question concerning sectioning must," he said, "be considered from a practical standpoint," and asked as a first question, "Where should the sectioning be done; into how many ability groups should classes be divided?" There is justification for having a three-level division in view of all of the information available, and it appears from a study of probability curves that both the highest and the lowest sections should be about one-half as large as the section of average ability. "One should then consider," he said, "the way in which the make-up of the sections should be determined."

There is an apparent danger in the sectioning of classes in physics on the basis of general intellectual differences, as judged by the results of a so-called intelligence test such as the Army Alpha test. Such tests are likely to be too linguistic in character. Physics requires a different type of mind and training than that disclosed by tests of the general intelligence type. This is shown by the difference between the marks given by college teachers of natural science and by teachers of language. Tests which relate more definitely to physics are desirable as a means of forming sections.

A further disadvantage of the so-called objective type of examination in relation to the sectioning of classes is that they are essentially tests of reactive rather than of creative abilities.

As a third point, Professor Dearborn remarked that the advantages of ability groups should be carefully considered. In the first place, it makes both the teaching process and the learning process easier. This is indicated by the results of tests showing the great range of ability of students in a given subject or class. It is especially advantageous for the able student who craves original tasks and will follow a topic far beyond the confines of the assigned text book.

"Quantitative measures of the results of sectioning," Professor Dearborn said, "are few, though there are some experiments of this sort." In this connection he quoted the Symonds-Moyer experiment on the results of sectioning. In this experiment it was found that the superior and the medium students did somewhat better in the segregated classes than in the mixed classes, but that the inferior students did better in the mixed classes.

Another practical question in connection with ability grouping advanced by Professor Dearborn is the difference of method to be used in the various sections. This question may be stated more concretely—"Should the group of high ability advance through the usual curriculum more rapidly or should it pursue an enriched course of study? There are advantages in both of these methods," he said, "the first offering the opportunity for the abler students to complete the course

in less time and thus get an earlier start in their professional work. The advantages of the enriched curriculum are of course obvious."

Certain criticisms of ability-grouping have been advanced and must be considered. The first of these relates to the type of test used. Since these tests are more of reactive ability than of creative ability, some have questioned the validity of sectioning on such a basis. Second, ability-grouping has been said by some to constitute educational determinism. Third, ability-grouping may make for invidious distinctions; the method is said not to be "democratic." Educational opportunity should be equal for all and not conditioned by one's ability. It is to be noted in this connection, however, that ability-grouping need not restrict the opportunities for the lower sections, but may even increase them and make it possible for the student to do a better grade of work than he would do if he were sectioned with those of superior ability.

"The most important criticism of sectioning on the basis of ability," Professor Dearborn said, "is that the dull student needs the stimulus of the brighter." No such criticism is offered, however, in other fields of college work; no one expects, for example, the star athlete to race with the novice.

The final criticism is that the gifted pupils may be overworked. This, however, does not seem to be a real danger; it is probably best to have all students working at approximately the level of their highest possible achievement.

HOW MAY PHYSICS BE MADE OF MORE VITAL INTEREST?

By W. L. Severinghaus, *Assistant Professor of Physics,*
Columbia University,
July 27, 1928.

Every now and then some one asks, "And what do you teach?" When they learn that it is physics they exclaim, "And how could you ever be interested in that?" The answer to this second question is difficult. How do we get suf-

ficiently interested in any field to want to spend our lives in it? About the best we can say is that we just naturally like it. Some may perhaps be able to attribute their decision to a definite experience or to a very fine teacher or to enthusiastic friends or to the life story of some great genius. But after all there must be a natural tendency in that direction and a certain native fitness for the work. That native fitness is not created by the teacher but is the clay without which the potter can mold no vessels. It must be remembered that the teacher of physics to pre-engineering students is not expecting to convert them into professional physicists; he is, however, blessed with a group that will average high in general scientific interest. That is his starting point. It lies with him largely to determine whether or not that average interest in physical problems will increase or decrease. He can so present the subject that it will appeal to an intelligent student or he can make the subject matter colorless and lifeless. I should like to state a few of the factors which are essential, in my opinion, to the development of interest and also tell you about a few educational experiments we have been trying in our department at Columbia University.

Some General Essentials

In the first place the teacher must have the gift, either natural or acquired, of imparting knowledge to others. He must be thoroughly familiar with the subject and enthusiastic about the work he is doing. He must be interested in the future as well as the present status of his subject and make some contribution to its development. He must be interested in the boys themselves and be willing to sacrifice his time to answer their questions and cultivate a personal acquaintance with them and their problems. Genuine friendliness on the part of the teacher goes far in maintaining and increasing the student's interest in his subject, whereas a single sarcastic remark in the class room may undo what it will take weeks to regain. In my opinion, it is always out of place to direct unpleasant personal remarks at a student before his classmates. Such conversation belongs in the office. The

conduct of both lecture and classroom work must be carefully planned and so selected as to furnish a real job for the best men in the class and at the same time be possible for the student of average ability. A snap course seldom holds the interest of those men who are really worth while.

The Lecture

The lectures should be rich in experimental demonstrations, illustrating principles, not aiming at exact quantitative results and not so complicated as to confuse the issue. I believe that engineering students as a class take the world in through their eyes more than through their ears. They remember what they see longer than what they hear. The projection lantern while it is very useful, is not a substitute for the real demonstration and is often overworked. The demonstrations should either be discussed clearly or not at all. It is a very good plan now and then to put on some snappy little demonstration and simply leave it to the students to discuss among themselves. Illustrations present themselves as the subject progresses. In addition to the demonstrations the lectures will also contain a very considerable amount of theoretical discussion that is either not contained in the text at all or not adequately treated. It is a great temptation in the lecture system to use a half-hour saying what the student could read with more understanding in the text in fifteen minutes. The lecturer's excuse is that he has to do it for the sake of continuity and completeness, but if too much of that is done the student discovers it and either quits reading the literature or goes to sleep in the lecture or both.

The Recitation Sections

In my opinion the large part of the classroom period should be taken up with the solution of concrete problems. These should be real problems stated in terms of real experience. Questions of the type, "Given a force of X dynes acting on a body of mass Y grams, find the velocity after t seconds starting from rest," are not stimulating to students of engineering. They may be good enough for mathematicians but the engi-

neering student wants his problems tied up with steam shovels, railroads, furnaces, generators, etc. To maintain interest in the classroom the work must be adapted to the intelligence and speed of the students. The only way I know of doing this is to divide the class into sections of not over twenty students, classified according to previous scholastic performance. The records in mathematics and chemistry may be used as a basis for the first division and after that the record in the previous semesters work in physics. The correlation between these three branches is high. The basis of the sectioning should be announced publicly and the reasons for doing it fully set forth at the beginning, it being made clear that there is no malice nor punitive motive back of the method. Nor should there be any attempt to assign the ablest instructors to the top sections. It appears best to have the instructors change sections at the end of the semester. We have tried shifting students from higher to lower sections or vice versa at mid-term but it does not in general seem satisfactory. Neither the instructors nor the students like it.

Reports on Assigned Subjects

The slower sections will probably have to spend all of their time, even if they have three recitations a week for a year and a half, getting cleared up and drilled on the essential points of the course, but the top sections may take up considerable additional work. There is no doubt about the fact that engineering students get too little practice in presenting material verbally to a group. I have been asking certain students from time to time to bring in a report to their section on some particular subject. For example one man took up the entire hour with a splendid presentation of Sellmeier's theory of dispersion, another took a half-hour to report Humphrey's chapter on lightning, another took a half-hour on Coolidge's high-speed electron tube, another the physical reasons for a change of the boiling point of a liquid by the addition of salts in solution, another the electrical and over-all efficiency of motors. This method seems to be particularly good for impressing on the students that after all the course is their course

and not the teacher's. One of the men was asked whether he understood the report on the high-speed electrons. He said that it had not been quite clear at the time but that a group had cornered the reporter in the dormitory later and made him explain it all. Anything that will get the students discussing intellectual problems among themselves outside of class hours is most desirable. In my opinion they do very much too little of it. It would seem better to have the selection of these topics made by the students rather than the instructor whenever possible.

The Final Examination

At the end of the semester all students are required to take the same three-hour written examination. These examinations consist of ten questions with sub-divisions in almost every question. All questions must be answered. These questions are made out with great care and constitute a part of the educational program of the course. It is our aim to make the questions interesting so that when a man does them well he feels a certain sense of mastery of the whole course. It was a source of great satisfaction to me to have the best man in the class say a year after he had taken the mechanics examination that he remembered it with pleasure and thought it the finest examination he had taken in college. We count the examination one-third and the daily recitation average two-thirds in arriving at the final grade, but the chief object in giving the examination is not to determine the grade but to help the student to organize the more or less scattered material presented during the semester.

The Undergraduate Seminar

From time to time various students had expressed a desire to consider subjects for which there was not enough time in the regular class hours. The idea of an Undergraduate Physics Seminar appealed to them. They appointed a committee and decided that while it was very desirable to have some member of the staff present to answer or perhaps ask questions it would be most helpful to have the papers pre-

sented by the students themselves. We proposed a set of topics and asked for volunteers to work them up and present them or what was still better to present topics of their own choosing. It was decided to meet every other Friday afternoon at five o'clock and to give the speaker not less than a month's time to prepare his work.

The chairman of the committee presides and after the presentation of the paper the meeting is thrown open for discussion. The subjects selected and presented this past semester were:

1. The electron theory of electrical conduction in solids.
2. The thermophone.
3. The special theory of relativity.
4. Theory of relativity continued.
5. Experimental evidences of the present theories of atomic structure.
6. X-rays and crystal structure with demonstrations.
7. A visit through the X-ray research rooms conducted by one of the instructors with a preliminary brief discussion of the apparatus to be seen.

The average attendance at these seven meetings was 19, composed of students from all sections as well as a few students in the college not taking this course in physics at all. One of the finest fruits of the seminar is that the undergraduate learns to use the library where he must hunt for material which cannot be found conveniently assembled in a few pages of his text book. In this search he discovers that there are sometimes conflicting opinions about questions in physics just as there are in other realms of thought. This discovery is apt to shock him a little at first but in the end is an encouragement to his personal endeavor.

One of the difficulties connected with this seminar is finding a suitable hour. In the first place the engineers' time is too rigidly apportioned, the afternoons being filled with laboratory courses. The five o'clock hour is about all that is left and that conflicts with athletic activities on the one hand and commuting to the suburbs on the other. Another

difficulty, which seems to be present in graduate seminars as well, is that the students are not as free as they should be in asking questions and thus putting life into the discussion. There is this constant fear with us all, I suppose, that we may ask something foolish.

The Laboratory

All teachers of laboratory physics must inevitably meet those students who are perfectly willing to take such facts as Boyle's Law for granted without taking the time to take down the data first, then work them out and then write them up. It is difficult to arouse enthusiasm over writing up a report on the vernier caliper. However, a deal of that kind of work has to be done by the beginner in order to acquire a certain understanding of what can be done experimentally and how to go about doing it. What kind of reports to require is a problem about which neither teachers nor students will ever agree. At any rate it appears certain that the teacher cannot leave it to the students in a large class to decide what experiments they will do and how they will report them. This needs careful supervision. But after this ground work is laid there comes a time when the student enjoys and has a right to some choice in building the super-structure. There seems to be such a large number of things in physics that *must* be looked into by one preparing for engineering that little time or strength is left to pursue any one line along which he happens to be particularly interested. One of the ablest students in my classes this spring told me that in his opinion the educational system was so organized that if a student had any original ideas or desires they would soon be killed and replaced by those of the regulation program. He felt that the public school would smother such interests or tendencies long before the boy reached high school and what the high school did not succeed in blotting out the college would most certainly finish. The statement is exaggerated but it contains a large element of truth.

To meet this need we have inaugurated a perfectly flexible elective laboratory course. The student is first asked what he

wants to do. It is then up to the staff to decide whether the problem he chooses is within the scope of the course and possible so far as equipment is concerned. For example, one man wanted to study some light filters and their use in stereoscopic projection, another wanted to make a study of organ pipes (he played the pipe organ), another designed and helped build a CO_2 meter of the Wheatstone bridge type and then calibrated it against an Orsat CO_2 meter studying the various physical factors that enter into the problem, and there are a great many. This experiment ran through the whole semester. Another wanted to run some tests on selenium and two types of photo-electric cells. Another one designed and built a laboratory set-up of the Lecher system for producing standing electric waves. Another worked with the oscillograph to test out distortion factors in certain radio circuits and tubes. These are simply illustrations of the variety of interests they have and will also serve to show how far the student is willing to go if the teacher and institutions can find strength and funds to go along. Once a student gets into that frame of mind the question of points and time required drop out of the picture entirely. He considers it a bargain to be turned loose as it were in a good laboratory for the small sum of the tuition fee. Well conducted laboratory courses, by the way, are almost always rated too low in points compared with the usual point basis in the lecture and recitation courses.

In addition to this type of student there are those who have no particular hobby they wish to ride but who ask the instructor to help them lay out a set of rather well developed exercises that have a more or less direct bearing on the general field in which they expect to specialize later on. They may, for example, if they expect to be chemists, desire a course made up of some experiments in electrical measurements and some in high temperature determinations, or if they expect to go into the field of communication, they may want to do a set of exercises on mechanical oscillations, wave motion, standing waves, resonance and damping as a fore-runner to their analogues in the field of electrical oscillations.

The laboratory courses are particularly adapted to cater to the individual whereas a general lecture course must be fitted to the group as a whole. We have this year arranged a whole new set of experiments at the request of the metallurgical engineers to meet their needs. This includes work on measuring electrolytic resistance, the Kelvin double bridge, transformation point determinations in steel and their use in hardening, measurements on magnetic permeability, various types of hardness tests, accurate expansion determinations over a wide range of temperature, X-rays and their use in studying crystal structures of metals as well as locating defects in castings. It should be stated that these men have already completed in the physics department a semester course on pyrometry .

It will be noticed that some of these exercises call for very elaborate apparatus. The Physics Department may not be equipped to do them all but there is no reason why the department should not supervise the course even when some of the apparatus and instruction is furnished by one or more of the other departments. In the above set, for example, the hardness tests were made in the Civil Engineering Testing Laboratory, the magnetic tests in the Electrical Engineering Laboratory and the observations with the X-rays in one of the commercial laboratories in the city. This course required a great deal of outside reading and whenever that became excessive, afternoons in the laboratory were dropped to compensate for it. When it was all over the boys said it was one of the most helpful courses they had taken. They seemed among other things to like the idea of cooperation between the departments and the commercial laboratory. There is a real danger of our various departments becoming water-tight compartments. A fuller cooperation between the various divisions will do much to dissolve the erroneous notion among many so-called practical minded engineering students that physics deals with dreams and the measurement of such small quantities that they may be neglected in any real problem "after you get out." I may say that the Mining Department

has already suggested the possibility of having us give the same or a similar course to their men.

Laboratory Equipment

In a discussion of student interest in laboratory work we must remember the importance of keeping the apparatus up-to-date and in good condition. I have seen the other method tried, namely of using rather poor, crude apparatus and urging the student to do the best he can with it and then analyse his results to see whether they are as good as the apparatus warrants. There is something to be learned by this method, but it almost invariably results in a lowering of the students' opinion of the laboratory and a distinct loss in his enthusiasm for the subject. Keeping a laboratory well equipped is very expensive, but I believe it pays educationally. Then the room itself must be attractive. We have just recently moved our laboratory from the basement of the old building to the tenth floor of the new. The view from the new laboratory is intriguing but that is an asset and not a liability. The other day when I opened the door to let a student in to make up some work he had missed he said, "I just love to work in here, it's the finest place on the campus." Students are sensitive to their surroundings. An examination showed that they had stopped to see the portraits of the famous physicists hanging on the walls in the hall just outside the laboratory. They *do* stop to look at charts and pictures of famous institutions other than their own. They *do* appreciate comfortable departmental libraries and study rooms and conveniences for computation.

Exhibition Rooms

Another helpful thing is to have good set exhibitions in easily accessible places. We are enjoying very much in our new laboratory the exhibition rooms on each side of the hall at the entrance to the building. On one side the display is usually self-explanatory and can be observed entirely through the window. This room during the past two years has held four exhibits; one on quartz, its properties and uses; one on

radium and the radioactive elements; one on the manufacture of optical glass and lenses used primarily in optometry; and at the present time one on X-rays and crystal structure. In the room on the other side of the entrance the pieces of apparatus set up are such that an attendant is required for their proper display. At the present time this room contains complete set-ups for the Barkhausen effect, Brownian movement, alpha ray tracks, polarization of light, a photo-electric effect in sulphur crystals, soap film interference patterns and the mixing of complementary colors. We arrange definite times with the students to meet with an instructor in this room and look these exhibits over as carefully as they may desire.

These then are some of the concrete suggestions I would offer for making the interest in physics more vital. Many others will occur to you and I feel sure we can not devote too much careful thought to the question for neither students nor teachers in this generation do their best work on the rational basis of its "being good for them." We need to cultivate the interest of the student and along with that interest convince him of the practical importance of what he is doing.

OBSERVATIONS CONCERNING TEACHING METHODS PRESENTED AT THE SUMMER SCHOOL

W. F. Dearborn, July 27, 1928.

Professor Dearborn began his remarks by referring to a point which was under discussion at the close of the previous day's session. In this discussion it developed that there was little question among the members of the group about the desirability of forming sections of the more gifted students in physics classes, but that in a number of colleges the practice of having two other sections—a medium and a low group—was being abandoned and the two were being combined into one. This led to the question, he said, of whether or not, it would be practicable in an engineering college for certain of

the better students to complete the engineering course in less than the usual allotted time. "There are some students," he said, "who ought to be able to do the work in less than the regular period. There are difficulties in this connection, of course, but the impression was left that this might be one of the best ways of challenging a good deal of present methods or organization and of teaching."

Professor Dearborn cited one or two instances in which the students have been able to complete the work in a given subject in very much less than the required time and to pass on to more advanced study. He also quoted from Oswald's "Grösser Männer," concerning the discovery of genius and its education.

After these introductory remarks, Professor Dearborn turned to the qualities the teacher should possess and said, "Now I am sure that we will all grant that a teacher who is really fired with the enthusiasm of learning and scholarship may be guilty of nearly all, if not all, the faults of the poor teacher, and may on this count alone stand out as one of the great teachers of his age. He may give no thought to his way of teaching but by the contagion of his own example—by his enthusiasm for learning, he may, through the operation of the still greater law of imitation, kindle the fires of learning in the student. There is no learning without stimulation and we should be sure that after this kind of stimulation there is rarely need of any other. It is to be noted, however, that some of the great contributors to knowledge, through discovery or invention, although they may have been great teachers, would seem to seal up their enthusiasm within themselves.

"But for the most of us, at any rate, who cannot soar to the heights of genius, some consideration of the ways of learning and teaching is most desirable, and that is why we have been here these three weeks. One of the things that I tried personally to emphasize in my opening discussion I have seen exemplified here over and over again, that teaching must take its cue from the learning process. The teacher must not only keep his eye on his students but he must take them as his point of departure. The notion of the teacher at the fountainhead

of knowledge, at whose feet the student laps up information, was noticeable by its absence here.

"Perhaps I should pause here to say that it is not my present function to throw bouquets any more than it is to throw acid, but I shall not proceed without remarking that you have served under some great teachers in this session.

"As to methods, aside from personalities, it has seemed to me that the outstanding teaching method which is uniquely superior in the teaching of physics, as compared with other academic methods, is the lecture-demonstration. Physics deals with things and with concepts regarding them. Its emphasis is on things rather than on words or symbols for things. Events and processes, to describe which another might need to run to words or formulas, cannot be seen or felt. There has been no opportunity here to compare the results of the laboratory exercises with what the student may get from the lecture-demonstration. Educators believe in the maximum of learning by doing, but in the lecture-demonstration there may be a lot of doing on the part of the student himself—what the psychologist calls *kinæsthesis*—the direct sensing in their own muscles and nerves of the observed phenomena. That is why such demonstrations as Franklin's with the gyroscopic cat have a pedagogical value. I have a suspicion that most all physicists are what the psychologist used to call *motiles.* A good deal of their best thinking goes on in terms of the feeling of movement—motor imagery—rather than in terms of visual or auditory reactions and certainly more than through verbal means. Further, they can best impart this very necessary way of thinking about physical events through the demonstration-lecture."

Professor Dearborn then turned to the lecture itself, saying that he would stress the fact that any general learning depends more than is easily realized upon clearness and vividness of stimuli and emphasized that much of the effectiveness in learning depends on such details as good light, clear print, good blackboard illustrations, clear, distinct enunciation, and precise, logical, systematic presentation on the part of the teacher. "As teachers," he said, "we must take pains not

to let other things distract from the clearness of the impression of the things to be learned. Unfortunate mannerisms of the teacher may have such distracting effect. This, of course, is one of the most delicate points to be discussed by teachers, but it is worthy of consideration by all."

Professor Dearborn then discussed in some detail the class demonstration method of instruction—the group discussion method—and concluded by referring to the contribution to the success of the session made through the contributions of the committees and the reports prepared by them. He also presented the following bibliography of texts on education which he recommended for general reading:

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SHOULD DESCRIPTIVE GEOMETRY HAVE A PLACE IN THE ENGINEERING CURRICULUM? *

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These are lively times for educators. Scarcely an issue of any of the prominent magazines comes to our desk in which we cannot find an article on some phase of education, and usually on college education. Some of these articles are written by teachers, or by teachers' wives, and some are written by outsiders, with or without teaching experience. Some are genuinely constructive, some are slanderous, and some are obviously written by some sorehead who has a grievance to work out of his system. The interesting fact remains that the leading magazines are devoting considerable space to our profession, our success or our futility, to the reactions of students, to the value of college education to the students, to coeducation, and to an infinite number of other perplexities. The colleges themselves never seem to tire of surveys of curricula and of appraisals of individual teaching efficiency, and I am sure that nearly all of us are heartily sick and tired of questionnaires. We serve on committees to investigate this condition or that. I served on a committee to investigate the quality of teaching of freshmen and sophomores. We met at regular intervals, indulged in much talk, sent out questionnaires, gathered statistics, tried to draw conclusions and to make recommendations, but the quality of teaching freshmen and sophomores remains exactly as good and exactly as bad as it was before the investigation. But whether the magazine article or the faculty committee deals with vocational training, student morality, or the ultimate height of coeducational skirts consistent with respectability, you may be sure that it comes

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from and is generated by the intense public interest in education.

The whole country is sold on education. If the Great War did nothing else, it convinced our entire population of the necessity for a college education. Who were the commissioned officers? Mostly college men. Who suffered the hardships and humiliations of the private? Mostly uneducated men. The public, including the privates themselves, very soon sensed this division based on educational qualifications, and quickly came to the conclusion that military preferment was not greatly different from leadership in civil affairs. The result was that our colleges have become crowded to capacity, and many of our most popular institutions have been able to gratify their desire to limit the enrollment by raising requirements and by selection of the most desirable. This limitation may be the solution that best meets the case, for certain it is that a large proportion of college students today do not come from the same intellectual stratum as that of the bulk of college students of a generation ago. The reason for this influx can be traced to two causes: (1) the unparalleled prosperity of the country, and (2) the desire for success, which they believe a college education will confer on them.

The demand for men of engineering education (I hardly dare call them engineers) has greatly expanded in the last half century and has fully kept pace with the increasing number of men graduating from such schools. No longer is the school required to develop skilled mechanics, for the factories are alive with them and can train all they need better than the schools. Draftsmen are sent out from high schools and night schools in numbers sufficient to keep the industrial drafting rooms well supplied with tracers and detailers, most of them good routine men and nothing more. No, the demand is not for mechanics, nor for draftsmen, machine operators, craftsmen, trouble-shooters, or clerks, for these are abundant and capable. The demand is for men of imagination, men who are keen-witted, clear-thinking, broad-minded, and humanitarian in their character. The engineering schools must

meet this demand, which comes from all directions and from all fields of endeavor, many of them of a non-engineering character. In our endeavor to meet it, we have revised our curricula, have reduced the time spent on purely technical studies, and have introduced more of economics, more of the humanities, and more pure science into our programmes.

Coincident with this curriculum revision arose a change in the opinion of educators as to the great object of an engineering education. The extreme specialization movement that captured the imagination of our master curriculum-builders of two decades ago was obliged to yield to a decided and almost unanimous reaction in favor of a more general engineering education, made more liberal and comprehensive by the addition of the branches previously mentioned. During the past decade we have heard our leaders earnestly pleading for a broader training for our students, and this prayer has been substantially echoed by the alumni. The reason is not hard to find. The high development of automatic machinery, mass production, and mass financing, and the astounding growth of business that has attended this country's financial ascendancy since the Great War, have brought new problems to our bankers, managers, statesmen, and even merchants, that only the engineer can successfully master. Competent men are needed and will be increasingly needed for the governing, advisory and supervisory positions in all lines of commercial, production, and construction activity. They need *our* graduates, for the engineering training is the only college training that fits a man for duties demanding responsibility, accuracy, vision, self-control, cooperation, mathematical ability, and the appreciation of the values and interpretation of statistics. Our graduates acquire these because they alone of all college graduates are compelled to pass two and one half years of mathematics, three to five years of physics, chemistry, and other sciences, no small amount of economics and business courses, most of the humanities required of liberal arts graduates, a large amount of applied science, such as mechanics, hydraulics, thermodynamics, electrical design (you

know them all), and in addition to all these, and by no means the least of them, descriptive geometry.

Why descriptive geometry? Despised and rejected of men, sometimes even threatened with extinction from the curriculum! Earlier in this paper have "vision" and "imagination" been referred to as desirable attributes of our industrial leaders; all analyses of character declare them such. Tell me of anything that arouses these qualities more effectively than does this branch of learning, which is not exactly drafting, and not exactly mathematics, although its title suggests both.

First, what *is* descriptive geometry? Many definitions are found, about as many as there are books on the subject, since every author feels that he must vary slightly the definitions offered by his predecessors, for fear of suspicion by his associates that he is not the original lexicographer. Some of its definitions which come to my mind are, "the science of drafting," "the grammar of drafting," "space geometry," and "the solution of problems relating to objects in space by the use of their projections on imaginary planes or other surfaces," and other assortments of words all meaning the same thing. These definitions are suggestive and in part correct. If it is defined as the science or grammar of drafting, we depend on the definition of these three expressions. In our use of them we assume that these words all have definite meanings to the student through his previous study of science, grammar, and drafting, so that they have become established in his mind as genuine conceptions, and therefore need no further defining. It is quite clear to me that, however variously we may construct our definition, all of us, who teach this subject, have a clearly defined idea of its meaning, its purpose, and its necessity, and I think that idea is virtually identical in its essentials with all of us. This means that I have the pleasant task of trying to convince a body of men who are already converted to my way of thinking.

Let us examine, then, and try to formulate the beneficial effects of this study and its reason for incorporation in a curriculum intended to produce engineers. We have already

claimed "vision" and "imagination" as two of the foremost assets in the equipment of an engineer, so let us apply this test to descriptive geometry. My belief is that the mere solution of problems in drafting, valuable as it is, is *not* the main purpose of this study. Its greatest contribution to engineering education is the development in the student the power of logical thinking, the ability to analyze, and the faculty of visualizing a proposition. This power of visualization has been frequently described as "the ability to think in three dimensions."

It is far more than that. It actually includes the entire range of the imagination, not merely to be able to expand flat projections into tangible objects in space, but have an insight into drawings that those not so gifted do not possess, and also the power to conceive vast projects, to evoke into reality things and ideas that never before existed. Such an imagination is the highest possession of our great engineers, inventors, scientists, prophets, financiers, merchants, and empire builders.

But, you object, it is absurd to credit descriptive geometry with all this; it cannot develop mere students into great inventors and merchant princes. Of course not by itself, but it can start into activity this faculty, which lies dormant and inert in the souls of most men. Previous to the student's commencement of the study of descriptive geometry, what stimulus to the acquisition of this quality has he received from his studies? What has he learned in high school? Facts, facts, facts, more facts and nothing but facts; facts of history, facts of science, facts of language, and other useful facts, to be forgotten easier than learned. Does the memorizing of multitudes of dates, equations, irregular conjugations, foolish systems of weights and measures, and a miscellaneous assortment of rules provide any appreciable stimulus to the imagination, or help to develop it? If one may judge by the average product of our high schools, the answer is easy. Employers are begging the schools to send them men who can *think*, and my experience is that very little real thinking is done by

high school graduates, and that their minds are only capable of routine assignments. If descriptive geometry will endow them with even a small amount of perspicacity and reason, it will justify all the curriculum space it occupies, *and more*.

If I thought that the mere solution of problems and the application of the study to drafting proficiency were its sole purpose and its only claim to a place in the curriculum, my advice would be, "Incorporate descriptive geometry at once and forever into the course in engineering drawing, search out the *easiest* ways of solving all problems, and do away with all of those that have little or no practical application. Cultivate manual dexterity and lettering skill, and let the intellectual values be omitted entirely." A certain textbook, which reduces all solutions to a single one and avoids all problems of more than slight complication, would provide the ideal medium for this purpose. Nevertheless, there is still need in our various curricula for mental discipline and I am convinced that to take the attitude just described and to withdraw descriptive geometry would be a staggering loss both to education and to future civilization.

In my experience I have known many fine draftsmen, men who could execute and letter, men who could design rather complicated machinery, and who could check the designs of others. Yet, if you asked these men to measure the angle between two oblique planes, as, for example, the valley angle in some roof, or to do many other fairly simple problems in descriptive geometry, they would be unable to work them even in a considerable length of time. These men are still draftsmen. They are paid by the hour and are laid off in slack times, because their employers know that plenty of good draftsmen will be available whenever business may pick up.

A question I sometimes ask my students, when a discussion over the practical use of descriptive geometry arises, is, "What is the difference between a draftsman and an engineer?" Since they can seldom give a satisfactory answer, I tell them of some draftsman who makes a beautiful drawing of a machine, perfect from his standpoint, the lines all neatly drawn,

the lettering clear-cut, the dimensions accurate, and all finished surfaces carefully noted, with tolerances given where necessary. Then the checker examines it and pronounces it O. K. And then it goes to the chief engineer for final inspection and approval. He examines it rapidly and points out a weak spot here, an assembling difficulty there, and declares that it will have to be completely redesigned, and suggests changes. He sees that the proposed structure or machine may be undersized in some part so that a breakdown is likely when the load is applied, or it may be too expensive to produce, hence unable to meet competition, or it may be faulty in mechanism, so that it will not even work. All these the engineer sees, because he has the power of insight into the very heart of the design, although he may be a poor hand at lettering. This superiority makes him a better draftsman than any of the skilled executants in his drafting room. I believe that the study of descriptive geometry accounted for a large share in the development of this power that is his.

One must admit that the student's interest is mainly aroused by the assignment of *practical* problems. He does the abstract assignments largely through compulsion and the fear of low grades. He fails to see any significance in problems dealing with points, lines, planes, and surfaces, and yet, it seems to me, that these must constitute the fundamental training. But until the drill in these fundamentals has been forced on him, and he is required to learn their analysis, he has not arrived at the mental condition requisite to their application to the more interesting practical problems. So, although he does find this grind tiresome and unprofitable, he needs it and he lacks something if he does not get it. Usually, and without warning, something related to real life appears to him, the veil is raised from his vision, and he is aroused to its real meaning. Nevertheless, it is only through the work of mastering the analysis of the abstract problems that he acquires habits of reasoning and logical thinking.

You may apprehend from this that I have scant respect and sympathy for many of the so-called aids to the mastery of

this subject. I firmly believe that descriptive geometry would be better taught and better mastered if these devices were omitted entirely. Too much dependence on models of problems and coordinate planes for your explanation will cramp, if not destroy, the power of visualization and independent thought in the student. And in the same class with these are made-to-order "layouts" of problems, which relieve the poor student "of most of the tiresome detail of constructing his own layout," to quote one prospectus. These artificial aids are, in my opinion, the last word in futility; they encourage lazy mentality and eliminate the very objects sought. There is an actual benefit to the student in being required to construct his own layout from a written description, and it far overbalances the performance of a larger number of standardized problems from which the real obstacle and the real nourishment have been extracted. We live in an age of automatic handling, mass production, mass construction, and mass management, but, thank God we are not wholly given over to mass education, and my fervent prayer is that the youth of our country will never see the time when their brains are atrophied by sugar-coated training and the spoon-feeding methods of education striven for by so many lazy-minded teachers, and even by many who are mistakenly and industriously striving for better results.

Another innovation that is almost as vicious as mass production in teaching is the reduction of all solutions to the single one of projecting the problem on an auxilliary plane. It is well to know how to use the Q-plane solution, and for many problems it is superior to the mathematician's method. But many cases exist where the latter is more suitable and more convenient to employ, and it is a good idea to have more than one way of doing things always at your command. Moreover, the mental activity acquired by being compelled to make an analysis of a problem is well worth the time necessary for its study.

To state my credo in brief, I believe that descriptive geometry is worthy to rank as one of the important brain develop-

ers in the curriculum; that it should not be consolidated with engineering drafting, nor even be made to serve as a mere aid in the solving of the more difficult drafting problems. I respect and appreciate the sincere endeavors of those of my colleagues who are earnestly striving to raise the standard of teaching the subject, even though they vary in the most fundamental essentials from my own ideas, and I have no criticism to offer as to their motives. We do not all think alike and cannot be made to take identical views of objectives, methods, and ideals. If we did feel the same, progress would be stopped. Some of us think as I have outlined and some of us think that the covering of large territory by the *easiest* means possible will accomplish the greatest results.

We often read in publishers' announcements, and sometimes even in the author's introductions, that the method used in this or that textbook will produce the greatest classroom efficiency, because the solutions and presentations conform most closely to industrial drafting room practice, or because by this method the largest number of problems can be solved, or that the civil, mechanical, electrical, or mining engineer will find problems adapted to his particular field. As I see it, all these claims are made with a warped understanding of the greatest benefit to the student which this study can confer; namely, the development of his latent power of logical thought, reasoning power, imagination, and the insight needed to make of him a great engineer.

A SHORT HISTORY OF DESCRIPTIVE GEOMETRY*

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Gaspard Monge, who was born at Beaume, France, May 10, 1746, and died at Paris, July 28, 1818, is quite universally and properly given the credit for discovering and systematizing the subject of descriptive geometry. But in giving him this signal honor it should not be forgotton that Amédée Francois Frezier, a French infantry officer from 1702–1707, and later an engineer in South America and San Domingo, by means of his work on stereotomy as applied to stone cutting and architecture published in 1738 and revised in 1760, laid at least a part of the foundation upon which Monge may have later built; nor that Johann Heinrich Lambert who published "Freye Perspective" in 1759 and later in 1773 did some substantial research in descriptive geometry.

The discovery, if it may be called that, of descriptive geometry by Monge was not accidental. While still in school, he observed "that the operations connected with the construction of plans of fortification were conducted by long arithmetical processes . . ." and he at once substituted for this a geometric method of his own devising. So startling an innovation was this method, that his instructor at first refused to examine it but once examined the method was received with enthusiasm and Monge was not permitted to divulge his new methods.

In 1768, when twenty-two years of age, Monge was appointed professor of mathematics in the Military School at Méziéres. In 1794, at the age of forty-eight, he accepted a professorship in the Polytechnic School in the establishment of which he had taken an active part. It was during these

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years (1768–1794) that Monge developed the science of descriptive geometry. Compelled as he was to withhold his discovery from the world, Monge with some bitterness no doubt said to two of his pupils in 1780: "All that I have done here by calculation, I could have done with the ruler and compasses, but I am not allowed to reveal these secrets to you," and it was one of these pupils—S. F. Lacroix—who appears as the only challenger of Monge's right to his discovery by publishing in 1795 the method of descriptive geometry. Monge also published the method the same year, first in the form in which his lessons had been taken down by stenographers during the short four months existence of the Normal School at the beginning of the year, and again in revised form in the *Journal* of the Normal School, and still again in 1798–1799.

It was after the closing of the Normal School, and the opening in the latter part of 1795 of the Polytechnic School where Monge taught descriptive geometry that he could give publicity to his methods, and thus came to be recognized for his epoch-making contribution to mathematical and graphical science.

Of the man himself this may be said: As a boy he showed rare ability and at the age of fourteen constructed a fire engine which was put into service, and at sixteen he was teaching in a secondary school at Lyons. In later life he accompanied Napoleon on his Egyptian campaign, and was once Secretary of the Navy. His contributions to the field of mathematics and science are far more extensive than can be recorded here, and extended into both the fields of pure and applied mathematics.

Monge was an inspiring teacher and had as his pupils many famous men of France. He had, according to one of his biographers, ". . . and inimitable manner of explaining the most abstract truths and making them intelligible by the language of action. However, it was only by struggling with his nature that he had been able to become an excellent teacher. He spoke with difficulty, almost stammering. He had in his

speech a vicious rhythm which made him prolong falsely certain syllables and cut short others. His face habitually calm, presented the appearance of meditation but when he was speaking it seemed as if one suddenly saw another man, a new fire shone suddenly in his eyes, his features became animated, his face became inspired."

Monge died in 1818 a broken man. Being an ardent partisan of Napoleon, he was deprived by Louis XVIII of his rank and his honors. This and the destruction of the Polytechnic School preyed upon his mind heavily and "he passed away in silence, without suffering, without fear, without hope."

Monge's successor in France seems to have been Jean Nicolas Pierre Hachette (1769–1834), who became a professor of descriptive geometry during Monge's absence in Egypt. in 1822 he published a "Treatise on Descriptive Geometry."

From France, Monge's descriptive geometry spread to Germany and there was taught by G. Schreiber, a professor in Karlsruhe. In 1828–1829 Professor Schreiber published a descriptive geometry in German.

Descriptive geometry was introduced into the United States in 1816 at the United States Military Academy at West Point by Claude Crozet. After graduating at the Polytechnic School in Paris, he had been artillery officer under Napoleon. From 1816 to 1817 he was assistant professor of engineering at the Academy, and from 1817 to 1823 full professor. E. D. Mansfield has given us some interesting recollections of Crozet's earliest teaching at West Point. The junior class of 1817–18 was the first class which commenced thoroughly the severe and complete course of studies at the Academy. Of Professor Crozet, Mansfield says that he was to teach engineering, but when he met the class he found that he would have to teach mathematics first, as not one of them had had the necessary preliminary training in pure mathematics for a course in engineering. "The surprise of the French engineer, instructed in the Polytechnique, may well be imagined when he commenced giving his class certain problems and in-

structions which not one of them could comprehend and perform."

Among the preliminary studies we find that descriptive geometry was included. "We doubt," says E. D. Mansfield, "whether at that time more than a dozen or two professors of science in this country knew there was such a thing; certainly they never taught it, and equally certain there was no textbook in the English language." This science, founded by Monge, was then scarcely thirty years old. Crozet meant to begin by teaching this branch, but a new difficulty arose. Just then he had no textbook on the subject, and geometry could not be taught orally. What was to be done? "It was here at this precise time that Crozet, by aid of the carpenter and painter, introduced the blackboard and chalk. To him, as far as we know, is due the introduction of this simple machine.[1] He found it in the Polytechnic of France."

"Crozet," says E. D. Mansfield, " did not more than half understand English. With extreme difficulty he makes himself understood and with extreme difficulty his class comprehended that two planes at right angles with one another are to be understood on the same surface of the blackboard, on which are represented two different projections of the same subject." The first problems were drawn and demonstrated on the blackboard by the professor; afterward they were drawn and demonstrated by the pupils, and then carefully copied into accurate drawings.

[1] While Crozet may certainly be credited with the introduction of the blackboard into West Point, historical records show that one Reverend Francis Xavier Brosius of Boston antedated him: ". . . in the winter of *1813–14*, during my first college vacations, I attended a mathematical school kept in Boston by the Rev. Francis Xavier Brosius, a Catholic priest who had fled to this country from persecution in France. He was a man of much learning and of unaffected, cheerful piety. On entering his room, we were struck at the appearance of an ample *Blackboard* suspended on the wall, with lumps of chalk on a ledge below, and cloths hanging at either side. I had never heard of such a thing before. There it was—forty-two years ago—that I first saw what now I trust is considered indispensable in every school—the blackboard—and there that I first witnessed the processes of analytical and inductive teaching." From Barnard's *Journal of Education*, 1866.

In 1821 Crozet published his "Treatise on Descriptive Geometry," for the use of cadets of the United States Military Academy at West Point, thus antedating all but the original books on the subject. The first eighty-seven pages were given to the elementary principles, and the next sixty-three pages to the application of descriptive geometry to spherics and conic sections. This is, according to our information, the first English work of any importance on descriptive geometry, and the first book published in this country.

Crozet has been called the father of descriptive geometry in this country. He taught this as preparatory to engineering. It may justly be said, also that the course of military science was greatly developed by him.

Mr. Latrobe favors us with the following recollections of him. "There are persons whose appearance is never effaced from the memory. Of this class was the professor of the art of engineering. Colonel Claude Crozet, a tall, somewhat heavily-built man, of dark complexion, black hair and eyebrows, deep set eyes, remarkable for their keen and bright expression, a firm mouth and square chin, a rapid speech and strong French accent. I can, even after the lapse of between sixty and seventy years, fancy that I see the man before me. He had been an engineer under Napoleon at the battle of Wagram and elsewhere, and the anecdotes with which he illustrated his teaching were far more interesting than the "Science of War and Fortification," which was the name of our textbook at the time. When he left the Academy he became chief engineer of the State of Virginia, which is indebted to him for the system that made her mountain roads the best, then, in America. Perhaps my recollection of Colonel Crozet is strengthened by my having seen him long after I ceased to be his pupil."

In 1823 the chair of Mathematics at the United States Military Academy was filled by Charles Davies who graduated from that institution in 1815. Following his graduation he was an assistant in the department of Mathematics, and held a full professorship from 1823–1837. Professor Albert

E. Church, of the class of 1828 and himself later the author of a descriptive geometry, says of him: "Professor Davies was then young, enthusiastic, a clear and logical demonstrator, and an admirable teacher. He had at once imbibed the spirit and fully sympathized in the desires of the superintendent, and labored earnestly to carry them out in building up a logical system of instruction and recitation, which required not only a thorough understanding of the details of and reasons for everything proposed, but a clear, concise, and complete examination of it."

"When Church was a cadet, according to his own statement, the methods of instruction were entirely new, and textbooks very imperfect. The professors and teachers had themselves to learn the true use of the blackboard, and the strict and detailed manner of demonstration. In algebra the best textbook that could be obtained was a poor translation of Lacroix. In geometry we had a translation of Legendre; in trigonometry, a translation of Lacroix; in descriptive geometry, a small work of Crozet, containing only the elements without application to the intersection of surfaces or to warped surfaces. These, with the whole of shades, shadows, and perspective, stone-cutting, and problems in engineering, were given by lecture to the class. Notes were taken by the cadets, the drawings made in our rooms before the next morning, then presented for examination, and at once recited upon previous to the following lecture. The sections in mathematics, philosophy, and engineering were of twenty cadets each, and were kept in three hours daily. Biot's work on analytical geometry was used, and Lacroix's calculus."

It was while connected with the Academy as professor that Davies published his descriptive geometry in 1826 which was the first extensive work on descriptive geometry in the English language. In the preface of his book dated at West Point, December, 1826, Davies states, "The subject of descriptive geometry, which is treated of in these 'Elements,' has not, as yet, been considered in this country as a necessary part either of a polite or practical education. It has been taught in the

Military Academy since 1817, but has not found its way into other Seminaries with a rapidity at all proportionate to its usefulness. The progress of science, like that of truth, is always slow; yet it compensates for its want of velocity in the steadiness of its advancement and the certainty of its success. In France, descriptive geometry is an important element of a scientific education; it is taught in most of the public schools, and is considered indispensable to the Architect and Engineer. Its intimate connection with Civil Engineering and Architecture, and the facilities which it affords in all graphic operations, render its acquisition desirable to those who devote themselves to these pursuits.

"The author is by no means indifferent to the reception which this work may meet with from the public; yet, he will not complain of a rigid criticism, if it shall appear that he has been instrumental in diffusing a knowledge of an interesting and useful branch of science."

"Professor Davies was succeeded in the chair of mathematics by Professor Albert E. Church. Church was a native of Connecticut, graduated at West Point in 1828, served as assistant professor from 1828 to 1831, also from 1833 to 1837. He was then acting professor of mathematics for about a year, and in 1838 he became full professor, retaining the chair till his death in 1878. He published four works which have been used considerably in American colleges. His 'Differential and Integral Calculus,' 1842, was more extensive than that of Davies. In the new edition of 1851 a chapter on the Elements of the Calculus of Variations was inserted. In 1851 appeared his Analytical Geometry, in which he followed somewhat the work of Biot on this subject. In 1857 his 'Plane and Spherical Trigonometry' was published. In 1865 appeared his 'Elements of Descriptive Geometry,' in the preparation of which he was aided by the French works of Leroy and Oliver, and by the elaborate American work of Warren.[2] Later editions give also the application of the subject to shades, shadows, and perspective. The 'Descriptive Geometry' met with larger sales than any of his other work."

[2] Warren's first "Descriptive Geometry" was published in 1860.

In 1902 when Church's widely used book was reprinted by his publishers this statement was included in the preface as a publisher's note: "The publishers have submitted this book to several eminent mathematicians and by their advise have retained the text unchanged as not being capable of improvement." Church, however, was revised in 1910 by George M. Bartlett of the University of Michigan, and the purpose of the revision as stated in the preface was "to meet new demands."

For forty years Church's "Elements of Descriptive Geometry" seemed to have satisfied the demands of technical education so far as the subject of descriptive geometry is concerned. It is true that S. Edward Warren of Rensselaer Polytechnic Institute in 1877 brought out a new text on descriptive geometry written as he stated in his preface—"To fill a need for a short text"—and the work of C. W. MacCord, a professor in Stevens Institute of Technology, appeared in 1895 and stated in its preface, ". . . and in the treatment of projections the aim is to lead the student to draw these in a matter of fact way as they would appear from different points of view, the express design being to keep out of sight as far as possible the artificial and often useless stage machinery of descriptive geometry." Whatever credit is given MacCord for his work in projection, certainly it must be recognized that his voice, so far as is known, is the first raised in doubt concerning the possible usefulness of this subject so much debated in later years. With these two exceptions, no books on the subject were published which attracted any attention until 1888 when Linus Faunce, an assistant professor in the Massachusetts Institute of Technology, wrote his "Descriptive Geometry," and until the year 1902 when William S. Hall, professor of graphics and mining at Lafayette College, published his work on "Descriptive Geometry." Faunce's book on descriptive geometry followed traditional lines, but Hall's was an epoch making publication since it was he who first used the third angle projection for his representations.

The foregoing statement concerning the unproductiveness of this forty year period should be modified at least to the extent of mentioning that during the years 1890–1897 a series of pamphlets were issued by Frederick N. Willson, professor of descriptive geometry, stereotomy, and technical drawing in Princeton University on the general subject of graphics and graphical representation, and later collected into a volume called "Theoretical and Practical Graphics," which included a discussion of Monge's "Descriptive Geometry," and an elaborate treatment of curved surfaces. Because his descriptive geometry was buried in an unwieldly volume quite unsuited for classroom use, and because of its unrelated title, Willson's book has never received the attention it deserves. In the opinion of the writer, it is one of the most scholarly treatises on descriptive geometry in the English language, and has been the source, without credit, of much material which has later been published.

The twenty-five year period following the publication of Hall's book in 1902 to the present time may be described as the most productive period in the history of descriptive geometry since no less than about thirty-five books have been issued. It is not the purpose of this paper to catalog all of the texts that have been published on descriptive geometry, but as a matter of interest to those who study the development of engineering education, it should be worthwhile to set down here the names of those books which have exerted an influence on the teaching of descriptive geometry.

In quick succession following the publication of Hall's book where the third angle projection was first used, came a similar book by Charles E. Ferris from the University of Tennessee also using the third angle method, and another by James E. Moyer, then an instructor at Harvard University who was the first author to apply the principles of descriptive geometry to the solution of practical engineering problems.

In 1905 Professor O. E. Randall of Brown University issued his text on the "Elements of Descriptive Geometry" which was one of the first texts to combine the third angle

with modern and practical methods of instruction. In 1908 George H. Follows, professor of machine design in Carnegie Technical Institute, published the "Essentials of Descriptive Geometry" and established the beginning of that era of texts which were written "to make descriptive geometry easy for the student to grasp." A reading of the prefaces of these books and of the volumes which follow them discloses a similar trend in all of them. The authors were teachers who had not yet found a text to suit them and so were themselves adding to an already long list of books on the subject.

In the series of three books which appeared from the Wisconsin campus in the period from 1909 to 1911 written by Phillips, Millar, Maclin, and Markwardt, an echo of Follows' endeavor is reflected, namely, "to make descriptive geometry easier for the student." And so without attempting to catalog a long list of texts which appeared from 1909 to 1920 let us pass over this period by stating that the effort of all the authors, including Anthony, Ashley, Smith and Higbee, seems to have been an attempt at better methods of presentation and wider application of the principles to the solution of drawing board problems. Only one exception appears to this generality: Adler's text on "The Theory of Engineering Drawing." In 1912 Professor A. A. Adler of the Polytechnic Institute of Brooklyn published the first of the texts designed to take the curse off of descriptive geometry by disguising its name! In his preface Adler states: "That texts on descriptive geometry appear with some degree of frequency, with but few, if any, additions to the theory indicates that teachers are aware of certain weaknesses in existing methods of presenting the subject."

Whatever other effect Adler's book may have had remains to be seen, but certainly it appears on the horizon as the forerunner of a new movement in descriptive geometry which may be described as an attempt at new methods of attack. O'Byrne's quaint thesis of 1920 may be mentioned here as the most futile and unique effort ever perpetrated by an American publisher. Cutler's contribution [3] in 1923 is an-

[3] "Descriptive Geometry" by Lawrence E. Cutler, 1923.

other record of this growing movement away from the orthodox, which has culminated in George E. Hood's "Geometry of Engineering Drawing" in 1926, and Kirchner and Eggers, "Descriptive Geometry" in 1928. Hood states ". . . an attempt has been made to approach the subject in a direct way," and Kirchner and Eggers argue that "the interrelation of the two geometries, descriptive and analytic, is recognized and its development is a feature of this text."

In this all too lengthy paper I repeat that I have not attempted to make a record of all the books which have been published, but I have endeavored to record what seem to me the more important and significant movements revealed by these texts. And in summarizing, I must frankly confess that the record of 133 years of descriptive geometry since the time of Gaspard Monge discloses that we have added little of importance to the body of this science, and that our attempts to make the subject more presentable and applicable have resulted only in continued dissatisfaction on the part of the users of our texts, and that we are now at the opening of a struggle to depart entirely from projection by Monge's methods to systems involving planes where you want them instead of at right angles, and to analysis in place of synthesis.

One may well ask, vulgarly perhaps, where are we at, and what are we doing about it, and should this group do anything? In answer to this first question, I have endeavored to give the facts as I have interpreted them. In answer to the second and third questions, I would like to go on record as stating that up to date this committee has done nothing about descriptive geometry and that in my opinion it should do the following things at once.

First, it should find out and state how much time, (either as a desirable allotment or as a minimum amount) should be allowed for the teaching of descriptive geometry.

Second, it should agree upon the purposes and objectives of teaching descriptive geometry.

Third, it should agree upon the content of the course, how it should be distributed and arranged, and how we may approach, at least, a solution of our obvious difficulties.

In short, here is a body of men primarily interested in the teaching of graphics in all its forms and in my opinion it is high time this group assumes the leadership and commands the attention which the importance of this fundamental science in the field of engineering education demands of it.

Note by author: The material in this paper has been compiled from: U. S. Bureau of Education, Circular of Information, 1890, Mathematics in the United States; "A History of Mathematics," by Florian Cajori; "History of Mathematics," by David E. Smith.

SOME ASPECTS OF ENGINEERING EDUCATION IN THE NEW SOUTH

THOS. F. BALL,

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As conditions present themselves in the South to-day, the majority of the engineers—whether they be electrical, civil, chemical, or industrial—are northern men, who have had the opportunities so long denied the young men of the South. This state of affairs is not altogether surprising when one has carefully considered the tremendous odds against which the South has had to struggle since the close of the Civil War. It is a well known fact that at the close of this unfortunate struggle the South was so impoverished as to make it practically impossible for the young men of this section to get an adequate training in the engineering profession, all of which has done much to retard the South in its educational and industrial growth. Of opportunity there was little, of money there was less, and those of our sons who were financially able do so were compelled to go North in order to find educational advantages and means of supporting themselves and those whom they left behind. Many of those young men who were fortunate enough to matriculate in the engineering schools of the North found themselves on the horns of a dilemma after completing their education: that is, they were torn between two emotions, the first of which was a more or less natural desire to return home and aid in the reconstruction of their devastated country; and the other, the absolute necessity of having to remain in the North for the purpose of making living.

What I have said concerning the young men who had engineering inclinations was equally applicable to those whose inclinations led them into any of the other professions, such as medicine, law, professorial work, etc. In order better to em-

phasize what I have just said, I should like to quote from an address delivered by Dr. Chas. L. Minor before a meeting of the Southern Medical Association in New Orleans at the time of his retirement as President. He said: "There is another very important matter which I wish briefly to discuss. Much as the South has suffered from the inadequate endowment of its medical schools, she has suffered even more from a habit which for years has been bleeding her of her most ambitious sons. Long before the Civil War, when we were an almost exclusively rural section, our young men were accustomed to go for their medical studies at first to Scotland, England, or France, and later to the North, because the greater urbanization found there gave greater educational and material opportunities." I wish to quote further from an address by Mr. Homer L. Ferguson, President of the Newport News Shipbuilding and Dry Dock Co., in which he said: "In 1888 I left North Carolina because father told us it was too hard to make more than a living here. But now one of my boys is coming back to this state because, there are to-day so many opportunities of making more than a living."

And, gentlemen, he is right! The time when all opportunities were in the North is passed, and the South offers many advantages to any ambitious young man, and as many in engineering as in any other calling.

Yet too many of our young men, followed the old habit formed by their fathers when it was a necessity, or else tempted by the dream of riches, leave their homeland which needs their help, their loyalty, their brains, and their ability in order to secure an education and living.

I am not arguing that every man should stay in his own section though he will develop more fully, I believe in the region whose ideas and ideals he drank in with his mother's milk, and whose people are bound to him by no slender ties. I do feel, however, that our young engineers—and especially those engaged in electrical engineering—should have their eyes opened to the opportunities that await them here, and

they should feel the duty that is theirs in contributing to the advancement of the New South.

In spite of the fact that the educational advantages afforded the young men of the South were so meager and inadequate at first, still we find Southern engineers, though trained in the North, occupying responsible positions in Northern industries.

The one thing which has done most to retard engineering education in the South has been a complete absence of well planned research work which should have been carried on not only by our engineering schools but our industries as well. This condition was largely due to a scarcity of funds, though much of the trouble can be directly attributed to the attitude which was held by many engineering schools and industries of the South. Neither educators nor industrial leaders were willing to appropriate money or time for carrying on research in pure science. This condition is in striking contrast with that found in the North, where research in pure science has always been considered of vast importance. To-day we find many of the largest industries of the country, such as General Electric Co., Westinghouse Electric & Manufacturing Co., American Telephone & Telegraph Co., and others, absolutely unwilling to leave research to chance. This is clearly evidenced by the fact that each of these companies spends vast sums of money annually in their own research laboratories, in addition to contributing to the support of similar research laboratories in some of the larger universities of the country. Only recently did the Massachusetts Institute of Technology receive a large grant from the Eastman Kodak Co. for the purpose of establishing a laboratory in which to conduct researches in photography at that institution.

Furthermore, I should like to lay particular emphasis upon the fact that most of the research sponsored by these large institutions has been in the past, and is to-day being carried out in the field of pure rather than applied science. Only too often do we come in contact with people from other sections who would have us believe that research in pure science is a

waste of time and money. This has been particularly true of the South in the past, but, thank God, the New South is slowly but inevitably up in order that she may be able to throw off the shackles of this indictment!

Moreover, the industries of the North have long ago learned the importance of making concerted efforts to push back the veil that has so long shrouded the fundamental realities of the physical universe! We, engineers and educators of the South, could not do better than follow the wonderful examples set by our Northern brethren. And not until the people of the South realize the importance of research in educational institutions and in industries alike will they be able to utilize their possibilities to the fullest extent. It has been said, and truly said, that the South today is exactly 25 years behind the North from the standpoint of research work. We, of the South, cannot possibly look for better days from an industrial viewpoint until the industrialists of this beautiful and richly endowed section of ours, namely the South, have been convinced, beyond the shadow of a doubt, that they must pay more and more attention to this all-important matter of research work. This, of course, would mean that these industrialists would have to look to our engineering schools and universities as places from which to recruit men capable of carrying on this important phase of their activities.

In any prosperous industrial section of our country you will find the industries and educational institutions drawing closer and closer together. In other words, each is beginning to realize its dependence upon the other. And before any section of the country can be really prosperous it will be necessary for the people and the legislature of the state in which the particular section is located, to realize the importance of research work in their educational institutions in order that their own men may have the opportunity to acquire the training necessary for making them leaders in the different industries of their section.

As a practical example of cooperation between industries and educational institutions I should like to dwell for a few

moments upon the plan conceived and worked out at the Massachusetts Institute of Technology. In 1919 Dr. William H. Walker, then Professor of Chemistry at M. I. T., advocated the establishment of a Division of Industrial Cooperation and Research at that institution. The plan was submitted to the faculty of the Institute and to several large industries, with whom the Institute proposed to cooperate, with the result that both parties gave their whole-hearted approval.

The adoption of the plan meant that the Division was to be composed of the most capable research men on the Institute faculty. It became possible, through this division, for the cooperating industries to submit to the Institute faculty any and all problems pertaining to their respective businesses. It has been definitely proven that both the Institute and the cooperating companies have been greatly benefited by this scheme. The Institute derives its benefit largely through retainer's fees which are paid by the companies for the services rendered by this Division of Industrial Cooperation and Research, while the companies themselves are able to get the very best information on the problems which have been submitted. The industries have learned that they are being more than repaid for their expenditures in that they can make use of the wonderfully equipped research laboratories of M. I. T., which, in themselves, cannot be surpassed in this country. Then, too, the industries have been able to offer many suggestions to the instructorial staff of the Institute as to the best way for presenting certain subjects.

It has been reported by Dr. Chas. L. Norton, Director of the Division of Industrial Cooperation and Research at M. I. T., that the income derived from retainer's fees amounted to a million and a quarter dollars during the first five years of the plan.

It is hoped that the people of the South may profit by what has been set forth in these pages, and that they may be quick to realize the importance of bringing about a closer cooperation between industries and educational institutions.

In order to promote a scheme, similar to the one described

above, the University of South Carolina, through its Engineering School, has recently organized a Division of Industrial Cooperation and Research, and has made announcement of same in a recent issue of the University News. It is sincerely hoped that the industries of the South will cooperate with the University in the furtherance of this plan.

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DISCUSSION OF REPORT OF COMMITTEE NO. 9, INDUSTRIAL ENGINEERING.

On pages 319–321 of the November, 1928, number of the JOURNAL OF ENGINEERING EDUCATION, I find a "report of Committee on Industrial Engineering." After a very brief summary of point of view and opinion there is a statement that in view of certain features of the "demands of industry" that "it would seem that Colleges of Engineering would be justified in doing two things:

1. Cut down the proportion of strictly technical and design courses in all standard branches of engineering.
2. Introduce courses setting forth fundamental factors included under the following heads:

    a. Industrial Statistical Method.
    b. Industrial Relations
    c. Accounting.
    d. Industrial Economics.
    e. Management."

The writer is heartily out of sympathy with any such ideas and feels that there is a great lack of analysis of the conditions involved and that the root of the matter has not been touched.

On page 319, paragraph 2, the statement is made, "It is quite evident that the administration of modern American Industry requires more of the scientific engineering view point" and "almost all of the growth which has taken place in the leading industries in this country, is directly traceable to the efforts of engineers in all lines." Paragraph 3, the first sentence says: "In view of the demands by industry for men with this viewpoint, we may well inquire where such a viewpoint is to be acquired."

Now it seems to the writer that since industry has recognized the special value of the type of training which engineering colleges have produced, there is every reason to believe that

the high grade engineering colleges are the places where such a viewpoint may be acquired. Therefore the statement at the beginning of the fourth paragraph, namely, "In the Colleges of Engineering it would seem that the standard engineering courses are inadequate, as regards certain types of industrial work" is almost absurd. It goes on to say: "Engineers in increasing numbers are entering the field of administration in industry and are using less and less of their training in specialized design courses."

This statement, which does not seem very clear, suggests a very wrong interpretation. Engineers may not follow up any one of the technical lines which they worked upon in college, but the type of training which they underwent in the mastery of those courses, is the very thing which industry is after. Also the type of mind developed under such training, coupled with the accurate, fundamental, scientific knowledge and with the orderly and systematic scheme of analysis in arriving at conclusions by the scientific method, is the type of trained mind which enables the engineers to tackle the problems of industry in such an efficient manner.

If we replace much of the technical analytical work of the present curriculum with some of the courses suggested, which are much more informational and indefinite, we will have taken the back-bone out of the training which has produced results so worth while.

Modern Engineering Curricula for undergraduates are in danger of being ruined by the removal of some of the best mental training courses, under the excuse that information should be offered in certain industrial problems. It should be remembered that it is not the information that counts during the training period, but the development of the analytical mind which can sift information, statistical or technical data and discover the truth.

In a four-year technical course, it is the opinion of the writer that much more can be accomplished of value to industry by the carefully planned curricula of the high-grade technical colleges of to-day, about as they stand, than would

be possible if some of these supposedly desirable courses were introduced at the expense of the definite technical courses which are splendidly adapted to the development of the scientific analytical type of mind.

FRANCIS W. ROYS,
Head of Dept.

WORCESTER POLYTECHNIC INSTITUTE.

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OBITUARY.

Alfred D. Cole.

Funeral rites for Professor Alfred Dodge Cole, for years chairman of the department of physics, were conducted at the Tenth Avenue Baptist Church by Dr. William Oxley Thompson, president emeritus, at 1:30 p.m. Monday, December 3, 1928.

Professor Cole died at his home Dec. 1, 1928, at the age of 67, after an extended illness. He was born at Rutland, Vt., December 18, 1861. His early education was obtained at Brown University, where he received the A.B. degree in 1884 and the A.M. degree in 1887. In his undergraduate work he showed a definite interest in the physical sciences and his subsequent training was an elaboration and development of this interest. During the year 1884–1885 he was a student of physics at Johns-Hopkins University, where he worked under the direction of the well known American physicist, Henry A. Rowland. For a number of summers he continued his studies in physics at Harvard University, at Cornell University, or at the University of Chicago. The year 1894–1895 was spent in research work at the physical laboratory of the University of Berlin, which was at that time under the direction of Professor Rubens. Those were the days in which electric waves were beginning to attract much attention. Professor Cole was one of the early workers in the field of physics. During that year he completed an important investigation on the refractive indices of water and alcohol for electric waves.

In 1885 Professor Cole came to Denison University as an instructor in physics and chemistry. He was subsequently promoted to professor of physics, a position which he held until 1901. During his years at Denison he built up the departments of physics and chemistry and contributed much to the intellectual and spiritual life of the college. That his

services to Denison University were valued very highly is seen from the fact that he has for a long time been a member of its board of trustees, having served in this capacity from 1901 to 1907 and from 1911 to the time of his death. In this position he exerted an important influence on the policies and program of the college, especially in the choice of its faculty.

In 1901 Professor Cole was appointed professor of physics at Ohio State University. He served in this position for six years until in 1907 he accepted a similar position at Vassar College. In 1908 he was called back to Ohio State as professor of physics and head of the department of physics, where for the past 20 years he has done much valuable pioneer work in building up the department of physics. When he assumed direction of the department its teaching staff numbered nine, but under his leadership it grew to 23 and the students enrolled in the department increased more than fourfold.

Professor Cole has been for many years a fellow of the American Association for the Advancement of Science. He served as secretary of Section B from 1906 to 1911 and as vice president of that section for 1913–1914. He was active in the work of the American Physical Society and a familiar figure at its meetings. As its secretary he did splendid work in the years 1912 to 1917, when physics was just beginning to make serious headway in America. From 1917 to 1920 he acted as associate editor of the Physical Review. He was also a member of the Optical Society of America, the Institute of Radio Engineers, the Ohio Academy of Science, Sigma Xi, and Phi Beta Kappa.

Frank Caspar Wagner.

Frank Caspar Wagner, President of Rose Polytechnic Institute, was instantly killed at 5:20 p.m., November 21, 1928, when the automobile which he was driving was struck by an interurban car as he was leaving the grounds of the Institute.

Dr. Wagner was born at Ann Arbor, Michigan, October 5, 1864, and he received his early education in the public schools of the place.

At the age of 19 he was graduated from the University of Michigan and for many years held the distinction of being the youngest man to receive the A.M. degree at that institution. In an additional year he completed the course in Mechanical Engineering.

He entered the employ of the Thomson Houston Electric Company at Lynn, Mass., in 1886, his work being mainly the erection of electric lighting plants. Towards the end of his connection with this company he was sent to Mexico where he had charge of the installation of a number of plants in and near the capital.

He returned to the University of Michigan in 1890 where he worked under Professor M. E. Cooley with the title of Assistant Professor of Mechanical Engineering. With Professor Cooley and Professor John R. Allen he tested a Nordyke pumping engine at Grand Rapids, Michigan, which test became later the subject of a paper presented before the American Society of Mechanical Engineers.

While at Michigan he made a number of tests on a Stirling boiler, in connection with a patent suit and thus began his work as an expert witness in patent litigation which was to occupy so large a share of his time up to the day of his death.

This patent work covered a wide variety of subjects but was mainly concerned with problems in steam engineering and heat transfer, some of which were to furnish the data for papers read before the engineering societies with which he was connected.

In collaboration with Mr. W. C. Ely of Terre Haute he designed the first rotary puddling furnace to be used in the local steel mills.

One of his more important cases was in connection with a cracking process for the production of gasoline.

In 1896 he was offered and accepted the position of Asso-

ciate Professor of Steam and Electrical Engineering at Rose Polytechnic Institute. This title was changed to Professor of these subjects in 1904 and to Professor of Mechanical Engineering 1920.

He was made President of Rose in 1923 which position he held at the time of his death.

Dr. Wagner held memberships in many engineering societies, among which were the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the Society for the Promotion of Engineering Education, and the American Association for the Advancement of Science. He was chairman of the Indianapolis section of the A. S. M. E. in 1927, President of the Indiana Engineering Society in 1928 and was appointed representative of this organization on the Assembly of the American Engineering Council, January 1, 1929.

Arthur Silas Wright.

Arthur Silas Wright died December 3, 1928. He has been Professor Emeritus of Modern Languages since 1924, at which time he retired and settled at Chevy Chase, Maryland.

He was born at Decatur, New York, in 1858. From Union College he took the degree of Bachelor of Art in 1882. In 1886 his Master's Degree was completed and from 1885–87 he continued his studies at the University of Leipzig. In 1921 he was honored by the degree L.H.D. (Doctor of Humane Letters).

In 1887 he was appointed Junior Professor of Modern Languages at Union College. He was called to Case School of Applied Science in 1893 and held the title of Profesor French and German until 1902, at which time he was made Professor of Modern Languages.

In 1924 he was suffering from high blood pressure and was

forced to retire from active teaching. He then continued writing and travelling.

Dr. Wright was the editor of three German to English translations and of the German Science Reader which was published in 1914. He was a member of the Modern Language Association of America, of Ohio, and of the Society for the Promotion of Engineering Education.

BOOK REVIEWS

Algebra for Secondary Schools. EMERY AND JEFFS. D. Van Nostrand Co. xii + 626, 5½ × 8. Pages. 1928. $1.85.

This is decidely not just another high school algebra. As an American text book it is unique. Its more than 600 small type, full, and closely printed pages represent an immense amount of painstaking and scholarly effort. No brief review can do it justice.

The principal distinguishing feature of the book is indicated on the title page by the significant words "Based on the Worded Problem." There is a total of 11,644 carefully graded problems, 3,019 worded problems in Part I, 208 pages, and 8,625 formal practice problems in Part II, 418 pages. No answers are given.

The student begins with Part II in which definitions and theory are briefly but adequately presented and many 'non-worded' problems proposed. In Article 5 he arrives at the statement "The student is now able to take the representation material in Group A, Part I and at similar statements as the work progresses." The book contains four four-place tables —trigonometric functions, logarithmetic trigonometric functions, common logarithms, and squares, cubes, and square roots.

The educational philosophy of the authors as stated in the preface is consistently adhered to. It is: "Any program that seeks to reduce useful work below the capacity of the student is to just that extent curtailing his education." "The authors believe that continuity of subject and of treatment is of the very essence of education; that the training in concentration of thought, in consecutive thinking, and in the consideration of an extended series of logically associated facts under few general headings is of far greater educational value than the mere acquiring of a multitude of facts without close logical relations."

There are inconsistencies in notations and references. Group H, named in Article 490, does not exist. As a text the arrangement is so 'different' that the authors should have added directions and advice concerning its use in the class room.

With earnest students and a teacher in sympathy with the philosophy of the authors, the book should prove very successful. At the very least a copy should find a place on the desk of every instructor in secondary school mathematics.

K. D. S.

The Engineer, His Work and His Education. By R. L. SACKETT, Dean of the School of Engineering, Pennsylvania State College. Published by Ginn & Co., Boston. 1928. Price $1.40.

In plain simple language, and in a direct straightforward way, the author addresses himself to the high or preparatory school boy who wants to know "What is Engineering?" Thus, in the early chapters, I find answered many questions which have been asked me time and again by prospective college students, their parents and their teachers. Certainly, any boy who will read the chapters of "Engineering as a Life Work," "A Brief History of Engineering" and "The College Course in Engineering," should be able to form some idea of his aptitude for engineering as a college course and as a life work. I wish the author had mentioned laziness as a cause for failure in college, but presumably this is included in the topic of "failure for lack of interest."

Individual chapters outline the main engineering courses, the kind of work that graduates of these courses follow and the professional life and opportunities in each field. I was glad to see the more specialized branches discussed as divisions of the broader courses. Thus under Civil Engineering, are included the following divisions: Highway, Railway Civil, Municipal, Hydraulic, Sanitary, Structural, Bridge, City Plannnig, and Surveying and Geodesy.

I enjoyed reading the chapter on "The Aesthetic, Cultural

and Romantic in Engineering" and personally gained from it a new point of view.

Finally, as examples to the young reader, there are twelve brief biographies of "Engineers who have made History," a notable list, from Leonardo da Vinci to Charles M. Schwab. Perhaps some of us would have changed somewhat the author's list, but all of his twelve have set their impress on the world, and their accomplishments should be an inspiration to every prospective engineer. Since at least seven of the men whose life work is described, are men of our own day and generation, the thought came to me that unlike statesmen, the engineer does not have to wait a generation before his services can be evaluated.

I shall use the book as a handy reference and recommend it to the engineering college administrators and teachers for this purpose. The general reader should get a new point of view of the engineering profession. Especially should the book be in every high and preparatory school to help correct there, the frequent narrow view of an engineering training and career.

E. A. H.

Electrical Engineering Laboratory Practice. EDISON AND NORRIS, University of Nebraska. Published by Ginn & Co. Price $2.80.

This book is divided into eleven chapters. The first six chapters deal with direct currents. Thirty-nine laboratory tests are outlined. The rest of the book is devoted to alternating current tests and forty-one tests are outlined.

Through the book each chapter introduces a definite subject with some theoretical subject matter. The tests are then suggested (for the students' further study of the subject) in the standard, Object-References-Apparatus-Form with a few questions or problems in conclusion.

The book should find application and be a helpful guide for undergraduate Electrical Laboratory work in many engineering schools.

R. C. G.